fleets for the future

# Electric Vehicle Procurement Best Practices Guide

# Preface

Funded by the U.S. Department of Energy (U.S. DOE) Clean Cities Program, the Aggregated Alternative Technology Alliance, known as "Fleets for the Future" (F4F), seeks to achieve nationwide economies of scale for alternative fuel vehicles (AFVs) through aggregated procurement initiatives. F4F plans to accomplish these economies of scale through a coordinated strategy designed to increase knowledge, lower the transaction costs of procurement, achieve better pricing, and address potential challenges arising from large-scale procurement initiatives, thereby increasing the deployment of alternative fuel vehicles in public and private sector fleets. The F4F team is comprised of national and regional partners with extended networks and relationships that can increase and aggregate the demand for alternative fuels and advanced vehicles. The project includes a regional procurement initiative spearheaded by each of the team's five participating regional councils, as well as a national procurement effort.

F4F will enable fleets to obtain vehicles that will both reduce emissions and operate at a low total cost of ownership. AFVs that use electricity, propane autogas, and natural gas all have desirable benefits, including less reliance on foreign petroleum, reduced fuel costs, reduced maintenance costs, and contributions to local air quality improvement. In order to achieve these savings, fleet managers must justify the higher upfront cost of investing in AFVs. By harnessing the power of cooperative procurement to reduce transaction costs and to obtain bulk pricing, F4F aims to reduce the upfront cost premium and make an even stronger case for investing in AFVs.

F4F does not detail purchase and use of ethanol, renewable diesel, or biodiesel, which are beneficial for many of the same reasons mentioned above. However, biofuels can be introduced into a fleet with little or no additional cost and require little or no additional technology upgrades to deploy. Hydrogen is not treated herein because the technology does not have a mature market and is not positioned for bulk purchasing.

In order to prepare stakeholders to successfully deploy AFVs in their fleets, the F4F team has compiled fleet management and procurement best practices specifically relevant to alternate fuels. These best practices build upon both the extensive information provided by the U.S. DOE and a number of recent successful case studies. The specific goal of these best practice guides is to educate procurement officers, fleet managers, and other interested stakeholders to plan for a large scale deployment of AFVs.

This document, the *Electric Vehicle Procurement Best Practices Guide*, covers the best applications for electric vehicles, technical considerations for their deployment, and procurement considerations. The F4F companion documents in this series include:

1. *Fleet Transition Planning for Alternative Fuel Vehicles*
2. *Guide to Financing Alternative Fuel Vehicle Procurement*
3. *Gaseous Fuel Vehicle Procurement Best Practices Guide*

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# Introduction

This guide is meant to help fleets and regionally-based buying cooperatives in understanding the benefits of deploying electric vehicles (EVs), as well as EV-specific considerations involved in the procurement process. Topics below cover both battery electric vehicles (BEV), which run solely on electricity as well as plug-in hybrid electric vehicles (PHEV), which use batteries to power an electric motor and use another fuel, such as gasoline, diesel, or fuel cells, to power an internal combustion engine. They are referred to as "EVs" throughout this document.

## Organization and Audiences

This document is organized around the concept that the process of transitioning to an EV fleet is inherently different from deploying other vehicle technologies and must be based on an institution's specific transportation needs — weighing both the organizational interests, finances, and operational efficiencies. The overall goal is to convey the value of a step-by-step, evidence-based decision-making process to determine a fleet's suitability to transition to EVs, followed by improved and streamlined procurement, and financing options that present the most economical pathway to get more EVs on the road quickly.

General information on EV technology and charging infrastructure has been extensively covered by the U.S. Department of Energy (DOE) and others; we cover these topics in limited detail.[1]

## Benefits of Electric Vehicles

Driving EVs instead of conventional vehicles can help reduce U.S. oil dependence, which has associated benefits for the country's economic and national security. EVs can also help businesses save money and insulate them from high and volatile fuel prices, while providing other performance benefits. PHEVs and BEVs are both capable of using off-board sources of electricity, and U.S. electricity is produced domestically from fuel sources that are low and stable in price. Both BEVs and PHEVs capture several key benefits of electric drive: [2]

### *Economic*

The stability of electricity prices combined with the high efficiency of electric motors, result in fuel costs that are typically 75% less than retail gasoline and diesel. A typical electric vehicle charging at the U.S. average electricity price of 11 cents per kilowatt hour (kWh) costs approximately 3.5 cents per mile to fuel. In comparison, the average internal combustion engine vehicle purchased in the U.S. in 2014 costs 12 cents per mile to fuel at a five-year average gasoline price of $3.39 per gallon. In the same way that gasoline costs vary by region, the price of electricity and mix of generation sources (e.g. coal, natural gas, nuclear, hydropower, wind, solar) also vary by region. The precise economic and environmental benefits from deploying EVs is a function of the specific location in which they are deployed.

Although fuel costs for electric vehicles can be significantly lower than similar conventional vehicles, initial purchase prices can be higher. These costs can be offset by fuel cost savings, federal tax credit, and state/private incentives. The federal Qualified Plug-In Electric Drive Motor Vehicle Tax Credit is available for PHEV and EV purchases until manufacturers meet certain thresholds of vehicle sales (200,000 units per manufacturer).[3] The credit provides $2,500 to $7,500 for new purchases, with the amount determined by the size of the vehicle and capacity of its battery.

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[1] See DOE's Alternative Fuels Data Center, http://www.afdc.energy.gov/, and other sources as cited throughout this document.
[2] Source: http://www.energysecurecities.org/wp-content/uploads/2016/01/SAF_1530-ESCC-Roadmap_v05_Singles_hi-1.pdf.
[3] http://www.afdc.energy.gov/laws

Additionally, the price of batteries used in EVs has declined by approximately 50% since 2008 and is expected to fall another 50% by 2020. This is important because the on-board battery can account for 25% to 40% of the upfront cost of an electric vehicle.

## *Efficiency*

Because EVs rely in whole or in part on electric power, their fuel economy is measured differently than conventional vehicles. EV performance is often measured in miles per kilowatt-hours (kWh) or kWh/100 miles. To make comparison with conventional vehicles easier for consumers, it is also common to see these metrics converted to a miles per gasoline gallon equivalent (MPGe) metric. Depending on how they are driven, today's most common light-duty EVs can exceed 100 MPGe, while some can drive up to 300 miles on a single charge.

## *Sustainability*

Electric vehicles also have significant emissions benefits over conventional vehicles. When operating on battery power, plug-in electric vehicles do not emit greenhouse gases (GHGs) or traditional tailpipe pollutants, such as oxides of nitrogen and sulfur. EVs have some impact on emissions in the power sector, where electricity is generated to fuel them. The life cycle emissions of a BEV or PHEV depend on the sources of electricity used to charge it, which vary by region. In regions that use relatively low-polluting energy sources for electricity production, EVs have a sizable life cycle emissions advantage over similar conventional vehicles running on gasoline or diesel. In regions that depend heavily on conventional fossil fuels for electricity generation, EVs may demonstrate a smaller life cycle emissions benefit. Even when electricity is produced from coal, the higher efficiency of EVs often results in a net reduction of GHG emissions.

In recent years, however, the carbon intensity of the U.S. electric grid has plunged to its lowest level since the end of World War II. As a result, a typical passenger electric vehicle charging on today's average U.S. grid mix produces the CO2 emissions equivalent of a 47-MPG hybrid. An EV charged by electricity from the average natural gas power plant is the emissions equivalent of a 56-MPG hybrid. Underlying the statistics is the fact that electricity is the only transportation fuel that has the potential to get substantially 'greener' over time, as the nation transitions more of its electricity production to renewable sources like wind, solar, and hydropower.

## *Fuel Diversity*

Electricity is generated from a diverse range of domestic fuels in the U.S., including coal, natural gas, nuclear power, and a half-dozen renewable energy sources. Less than one percent of U.S. electricity was generated from oil in 2014. The diversity of fuels used to generate electricity contrasts starkly with the current transportation system, which operates to its detriment almost exclusively on petroleum.

## *System Scale*

The electric power grid is truly a national system, reaching every home, commercial building, and industrial facility in the country. Because of this scale, electric vehicles enjoy a head start with deploying a refueling network. While transitioning to electric vehicles will require continued buildout of charging infrastructure, additional functionality, and continued reliability investments in the grid, the power sector's backbone—generation, transmission, and distribution—is already in place.

# Applications Best Suited for Electric Vehicles

Electric vehicles store electricity from the power grid in an onboard battery. The battery provides electricity to an electric motor, which provides power to the wheels. When operating on battery power, plug-in electric vehicles use no oil, sharply reducing fuel costs and emissions.

## Vehicle Specifications

The basics of EV technology have been written about extensively. The definitions below are sourced from two commonly cited sources, the U.S. Department of Energy and the Electrification Coalition.[4] There are two primary powertrain designs for plug-in electric vehicles:[5] battery-electric vehicles and plug-in hybrid electric vehicles.

### *Battery-electric Vehicles*

BEVs operate solely on the electricity stored in an on-board battery. The large format batteries in today's typical BEVs offer a driving range between 50 and 100 miles, with some newer makes capable of achieving 200-300 miles on a single charge. BEVs contain none of the traditional powertrain components of an internal combustion engine (ICE) vehicle. When the battery in a BEV is fully depleted, it must be recharged prior to driving the vehicle. The amount of time necessary to recharge a BEV can vary greatly depending on the size of the battery and the level of charger used, ranging from as low as 30 minutes on a DC Fast Charger to more than 12 hours on a Level 1, 110-volt outlet.

### *Plug-in Hybrid Electric Vehicles*

PHEVs are capable of operating solely on battery power – retaining many of the benefits of a battery electric vehicle – while also including a conventional gasoline engine that is integrated with the electric drive system. PHEVs typically feature significantly smaller batteries than BEVs, reducing the range that can be driven on electricity alone from as little as 15 miles up to 90 miles depending on the make and model. When the battery in a PHEV is fully discharged, the gasoline-powered system engages and provides power to the wheels over an extended range of miles.

There are numerous tradeoffs between BEVs and PHEVs. For the average U.S. driver who travels less than 40 miles a day, a BEV with 100 miles of range is more than suitable for everyday needs. For drivers with higher-mileage needs, PHEVs may provide a more practical solution.

A number of light, medium, and heavy-duty PHEVs and BEVs are available from a variety of automakers.

## Light-duty Vehicles

Light-duty refers to motor vehicles that have a gross vehicle weight rating (GVWR) of less than 8,500 pounds. This vehicle class covers the most common passenger vehicles (e.g. sedans, minivans, sport utility vehicles) and many of the most common pickup truck make and model combinations on the road.

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[4] Sources: http://www.afdc.energy.gov/vehicles/electric.html and http://www.energysecurecities.org/wp-content/uploads/2016/01/SAF_1530-ESCC-Roadmap_v05_Singles_hi-1.pdf.

[5] Other terms an acronyms are also associated with electric vehicle specifications. HEV (hybrid electric vehicle, which have no plug-in capability), PEV (plug-in electric vehicle), and EREV (extended range EV, which is a PHEV with a series hybrid drive system). For this guide, we will use the abbreviations EV to represent all electric drive vehicles, BEV for all electric-only vehicles and PHEV for all plug-in hybrids.

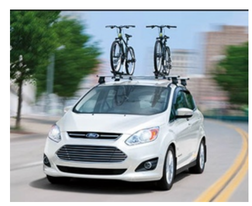
At the time of publication during model year 2016, there are 11 commercially available light-duty BEV models and 15 PHEV models. The table below shows some of the most common makes and models.

***Figure 1. Attributes of Several Common Model Year 2016 BEV and PHEV Makes and Models.***



| | Nissan Leaf | BMW i3 | Ford Focus |
|---|---|---|---|
| Category | BEV | BEV | BEV |
| Battery Size | 30 kWh[6] | 22 kWh | 23 kWh |
| MSRP | $34,200 | $41,350 | $29,170 |
| Incremental Cost[7] | $10,975 | $18,125 | $5,945 |
| All-Electric Range | 107 miles | 81 miles | 76 miles |
| EPA MPG Rating | 114 MPGe | 124 MPGe | 105 MPGe |
| Charge Time (240v) | 8 hours | 7 hours | 7 hours |
| Est. Annual Fuel Cost | $550 | $500 | $600 |





| | Chevy Volt | Ford Fusion Energi | Ford C-Max Energi |
|---|---|---|---|
| Category | PHEV | PHEV | PHEV |
| Battery Size | 18.4 kWh | 7.6 kWh | 7.6 kWh |
| MSRP | $33,170 | $33,900 | $31,770 |
| Incremental Cost | $9,945 | $10,675 | $8,545 |
| All-Electric Range | 53 miles | 20 miles | 21 miles |
| EPA MPG Rating | 106 MPGe | 88 MPGe | 95 MPGe |
| Charge Time (240v) | 4 hours | 2.5 hours | 2.5 hours |
| Est. Annual Fuel Cost | $800 | $900 | $900 |

[6] The Nissan Leaf now uses a 30kWh battery for model year 2017.
[7] Compared to a base Ford Focus 4-cylindar 2.0-liter engine with an MSRP of $23,225 and an EPA estimated annual fuel cost of $1,000.

Commercially available BEVs – especially those that are not considered luxury brands – most often fall into the compact or subcompact sedan class. These vehicles do not have a large amount of cargo space, can usually carry up to four or five passengers, and have a driving range between 50-200 miles.

Since EVs do not retain as much of their efficiency advantages at high-speeds, these vehicles are best suited for driving in urban settings with a lot of stop-and-go traffic and where speeds generally remain below 45 mph. In an ideal setting these vehicles need only a single charge per day to meet their daily driving needs. This may not always be possible, so case fleet operators should make their drivers aware of vehicle charging options away from 'home base.'

Commercially available PHEVs – especially those that are not considered luxury brands – most often fall into the compact to midsize sedan class. These vehicles have medium amounts of cargo space, can usually carry up to four or five passengers, and have an all-electric driving range between 15 – 90 miles. These vehicles are well-suited for a wider range of use cases because they have a gasoline or diesel engine to continue supplying energy once the electric battery is depleted. In reality, these vehicles can fit nearly any use case.

In either case the successful transition to EV relies on a fleet's ability to transition the maximum number of miles from petroleum to electricity. In the most basic sense, this means deploying EVs into use cases where the vehicles can expect to drive upwards of 10,000 – 12,000 miles annually. These may be difficult mileage targets for many light-duty vehicles to meet; however, high mileage vehicles are necessary to make the transition to EVs economically viable and to ensure environmental benefits are realized. A common practice to drive up the mileage on individual vehicles is to look at consolidating the number of vehicles in a fleet – a term called 'right-sizing.'

## Medium and Heavy-duty Vehicles

Medium-duty refers to motor vehicles that have a GVWR between 8,500 pounds and 10,000 pounds. Heavy-duty refers to motor vehicles that have a GVWR of more than 10,000 pounds. Medium-duty and heavy-duty vehicles cover a wide variety of trucks, passenger vehicles, and buses. Applications for these vehicle segments include cargo vans, street sweepers, refuse trucks, tractor trailers, buses (shuttle, transit, and school), and a large number of custom vocational/cab chassis configurations.

The number of BEV and PHEV options available in these segments is growing, but they are presently characterized by niche manufacturers working to establish scalable supply chains and vehicle availability.

Medium-duty vehicles available as BEVs are limited to a number of specific applications whose duty cycles ensure the vehicles have enough time to charge their larger batteries when not in use. The most common applications are step vans used to transport cargo or packages, terminal trucks used to haul semi-trailers around cargo yards and warehouses or intermodal facilities, and transit buses. More recently some manufacturers have begun to offer BEVs as school buses, class 8 tractor trailers, and refuse trucks.

While not quite the same as the PHEV configurations in the light-duty segments where the electric motor powers the drivetrain, there are some medium-duty/heavy-duty vehicle applications commonly referred to as PHEVs that operate in a slightly differently manner.[8] In these applications, a gasoline or diesel engine is used to power the drivetrain while an electric motor powers auxiliary services when the vehicle is idle. For example, electric utilities have converted some bucket trucks to use an electric motor for auxiliary services. While the bucket truck is stopped at a job site, the electric motor powers all the auxiliary services and the in-cab climate control system for a full work day without using the gasoline or diesel engine. While not a traditional PHEV, these applications can provide significant reductions in petroleum use and GHG emissions by eliminating the engine idling time that would otherwise be necessary to perform the work.

[8] These vehicles may also be referred to as Range Extended Electric Vehicles (REEV) or Hybrid-Hydraulic.

*Figure 2. Attributes of Several Common Medium- and Heavy-duty BEV and PHEV Makes.*



| | Transit Buses | Step Van | Cab Chassis |
|---|---|---|---|
| Category | BEV | BEV | BEV |
| Battery Size | 135-395 kWh | 60-125 kWh | 145-207 kWh |
| All-Electric Range | 140-160 miles | 90-150 miles | 100-155 miles |
| Example Fleet | City of Denver | UPS<br>FedEx | Frito Lay |



| | Terminal Trucks | Refuse | Bucket Trucks |
|---|---|---|---|
| Category | BEV | BEV | PHEV[9] |
| Battery Size | 200 kWh | 210 kWh | 14.2-28.4 kWh |
| All-Electric Range | 30-60 miles | 50-85 miles | 40 miles |
| Example Fleet | Port of Los Angeles | City of Chicago | Pacific Gas and Electric (PG&E) |

## Vehicle Conversions

Another possible mechanism to deploy EVs involves the conversion of an existing vehicle or engine to an electric or plug-in hybrid drivetrain. Such conversions provide options beyond what is available from original equipment manufacturers (OEMs). Certified installers can convert many light-duty and heavy-duty vehicles to operate on electricity alone or to improve the efficiency of conventional vehicle designs.

Systems converting vehicles to PHEVs require certification from the U.S. Environmental Protection Agency (EPA) or the California Air Resources Board (CARB). In some cases, conversions can affect the vehicle's factory warranty. Some companies perform conversions on in-service fleet vehicles. If a hybrid system will be installed on an in-service vehicle, that vehicle must have enough payload capacity to allow for the added weight and space requirements of the hybrid system components. Vehicles can be converted to PHEVs by adding additional battery capacity and on-board charging equipment. Some converted vehicles can achieve up to 100 MPGe until the auxiliary battery is exhausted, at which point the vehicle acts like a traditional hybrid vehicle.

Some examples of manufacturers providing certified conversion systems include: XLHybrids, Odyne Systems, Enginer, and Boulder Hybrid Conversions.

[9] When driving, these vehicles operate similar to a standard hybrid electric vehicle. The stored energy in the batteries is then used primarily to power the truck's aerial devices and auxiliary power needs without running the truck's diesel powered engine.

# Technical Considerations for Deployment of Electric Vehicles

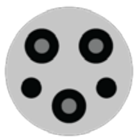
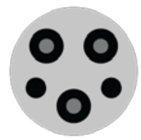
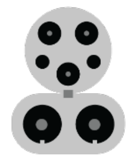
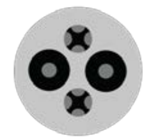
## Infrastructure Development

To facilitate mass adoption of EVs, both consumers and fleets need a broad network of charging stations. More than 30,000 publicly available charging stations, also known as electric vehicle supply equipment (EVSE),[10] are currently available in the U.S. Many of these are deployed to enable public charging. The majority of consumers do most of their charging while parked at home, whether using a specifically installed home charging station or a regular wall socket. Charging stations at workplaces and public destinations bolster market acceptance, signaling to motorists that charging capability is available away from home.

Charging equipment is classified by the battery charge rate and type of current supplied. Currently, available options include AC Level 1 charging (L1), AC Level 2 charging (L2), and Direct-current Fast Charging (DCFC). Charging times are of significant importance to fleet managers and vehicle operators, and they vary based on EVSE type, battery type, level of charge, and total battery capacity. Charging time can range from 15 minutes to 20 hours or more. A common measure of charging speed is how much time it takes for a battery to go from empty to an 80% state of charge, since charging slows down significantly as the battery reaches full capacity. For instance, a Nissan LEAF using DCFC may go from empty to 80% charge in approximately 30 minutes,[11] while achieving this same charge with AC Level 2 is likely to take several hours.

[10] http://www.afdc.energy.gov/fuels/electricity_infrastructure.html
[11] http://www.plugincars.com/electric-car-quick-charging-guide.html

*Figure 3. EV Charging Infrastructure Options.*

| AC Level 1 Charging | AC Level 2 Charging | DC Fast Charging |
|---|---|---|
| 2 to 5 miles of range per 1 hour of charging | 10 to 20 miles of range per 1 hour of charging | 50 to 70 miles of range per 20 minutes of charging, depending on the vehicle |
|  |  |    |
| J1772 charge port | J1772 charge port | J1772 combo · CHAdeMO · Tesla Combo |
| AC Level 1 EVSE (referred to as Level 1) provides charging through a 120 volt (V) AC plug. Most, if not all, plug-in electric vehicles (PEVs) will come with a Level 1 EVSE cord set, so no additional charging equipment is required for basic vehicle recharging. On one end of the cord is a standard NEMA connector, (e.g. NEMA 5-15 – a common three-prong household plug) and on the other end is a SAE J1772 standard connector. The SAE J1772 connector plugs into the car's J1772 charge port and the NEMA connector plugs into a standard NEMA wall outlet.<br><br>Level 1 is used for charging when there is only a 120V outlet available, but can easily provide all of a driver's needs. For example, 8 hours of charging at 120V can replenish about 40 miles of electric range, which will meet the daily driving needs of most consumers. | AC Level 2 EVSE (referred to as Level 2) offers charging through 240V (typical in residential applications) or 208V (typical in commercial applications) electrical service. Most homes have 240V service available, and because Level 2 EVSE can charge a typical EV battery in just a few hours, they may be installed at EV owners' homes and public charging stations. Level 2 can operate at up to 80 amperes and 19.2 kW for fleet operations. However, most residential Level 2 will operate at up to 30 amperes, delivering 7.2 kW of power. These units require a dedicated 40-amp circuit.<br><br>Level 2 equipment uses the same SAE J1772 connector and charge port that Level 1 equipment uses. All commercially available PEVs have the ability to charge using AC Level 1 and AC Level 2 charging equipment. Although Tesla vehicles do not have a J1772 charge port, they come with an adapter. | DCFC equipment, sometimes called DC Level 2 (typically 208/480V AC three-phase input), enables rapid charging for fleets and along traffic corridors at installed stations. There are three types of DCFC systems that work with different charge ports on the vehicle: J1772 combo, CHAdeMO, or Tesla.<br><br>The J1772 combo is used by Chevrolet and BMW, and uses the same charge port as with Level 1 or 2, but with an additional port receptacle that takes the two bottom pins of the DCFC connector. Early model EVs may not be equipped with the DCFC port.<br><br>The CHAdeMO is the most common of the three connector types and is used by Nissan, Mitsubishi, Toyota, and Fuji.<br><br>Tesla vehicles have a unique charge port and connector that works for all their charging options, including their fast charging option called supercharger. |

Reproduced from: http://www.afdc.energy.gov/fuels/electricity_infrastructure.html

While the public charging network will continue to grow, fleets will likely need to install their own infrastructure. Understanding the different options available based on the vehicles selected for deployment is critical and will inform the EV program rollout from the very beginning. The continually expanding availability of charging stations will be a critical component of successful EV programs, aided by the fact that charging can be located in a variety of locations. In addition, better battery technology, an expanded DCFC network, and wireless charging will speed charging times and further enhance the successful integration of EVs in fleets.

## Infrastructure Site Assessment and Demand Management

A successful EV deployment program depends heavily on positioning associated infrastructure to charge those vehicles and must be factored into the planning process. In many applications, there may be no additional cost to use L1 charging as vehicles can plug directly into existing 100V wall outlets. If faster charging is necessary, the upgrade to L2 charging can be relatively inexpensive—less than $1,000 for the charging unit alone. However, costs may increase if the facility also requires other infrastructure updates prior to installation of the charging unit. This may include trenching and laying conduit from a building to parking spaces or upgrades to the facility's electrical capacity. These costs should be estimated and factored into any total cost of ownership (TCO) comparisons completed prior to EV deployment.

By using best practices from this document and lessons learned from previous EV deployments, fleet managers can keep costs to a minimum. A cost-effective EV program deploys an optimal ratio of EV:EVSE based on parking locations, durations, and the time needed to charge vehicles and ensure normal fleet operations. A ratio of one EVSE plug per vehicle may be required, but the specific ratio will vary by fleet. It is also worth connecting with your local Clean Cities Coalitions[12] to ensure that all local, state, and federal incentive programs are being considered for EVSE implementation. Some utilities or local distribution companies may also provide incentives or have interest in collaborating to increase EV deployment and charging station use in their region.

Telematics data can be a valuable asset in determining where to site EVSE, and can help determine how many charging ports to install and what level of chargers are necessary. GPS route data common among telematics systems reveals specific vehicles, their locations, durations, and parking times. This data can be used to understand the optimal number of EVSE units that are needed to charge an existing or planned number of EVs deployed to a particular location. In addition, fleet and facilities management should understand their utility's rate structure and its impact on where to place EVSE, and when to charge the vehicles (i.e. electricity may cost more at peak use times, such as 5:00-7:00 pm). This information can be combined with facilities data to understand the true cost of installing EVSE in the optimal locations.

## Driver Education and Outreach

Successful EV deployment plans involve engaging employees early and often. Providing the appropriate level of training will ensure correct and safe operations. Particular topics of interest may include: safety while plugging the vehicle in to charge (i.e. inspecting the cord for cuts or frays and updating 110v outlets), consideration of pedestrians who may not be able to hear a moving EV, and remembering to plug in the vehicle at the end of a shift or trip. Some vehicle manufacturers offer EV trainings to dealerships and may also offer training to fleet customers. Check with the local Clean Cities Coalition to see if additional training opportunities exist.

Driving behavior is another important factor that affects EV performance and range. By following basic "eco-driving" habits, drivers can maximize the range of their EV and reduce unnecessary wear and tear.[13] For example, speeds over 50 mph combined with rapid accelerations can have significant impact on an EV's energy use. Also, pre-trip planning to combine trips and avoid unnecessary trips saves time and money by avoiding unnecessary stopping and starting, which will increase the overall range of an EV.

PHEV drivers are predisposed to falling back on their default driving behavior and use petroleum fuels rather than electricity. Management of a PHEV fleet requires some additional care to ensure that they are deployed into applications in which drivers can maximize the number of miles driven on electricity, access a variety of charging options, and not regularly default to the use of petroleum fuels.

[12] https://cleancities.energy.gov/coalitions/locations/
[13] http://www.afdc.energy.gov/conserve/behavior_techniques.html

### *Maintenance Training*

While EVs require much less maintenance than conventional vehicles, it is still important to have key personnel properly trained to perform diagnostics, maintenance, and repairs. Maintenance may be done in-house or outsourced to third party technicians. Specific arrangements should be made to ensure training for technicians who will be responsible for the EV fleet. Along with OEM training, others, such as the National Alternative Fuels Training Consortium (NAFTC), offer in-depth courses.[14] Over time, the trained and experienced fleet technicians will be positioned to train and mentor others, enabling other fleets in the region to scale up their capabilities to provide needed service. Another option could be to partner with an organization like a local chapter of the International Brotherhood of Electrical Workers to establish a local training program for vehicle maintenance technicians across organizations and in the private sector. This model has proved effective in Columbus, Ohio.

# Procurement of Electric Vehicles

An EV deployment plan based on meeting operational needs and economic outcomes will ensure that the technology is used appropriately and in adequate quantities. The following additional factors should be considered before, during, and after the transition to EVs.

## Developing Electric Vehicle Specifications on Requests for Proposal

It is important to consider and specify minimum requirements for the EVs you want your fleet to deploy, and then include them in bid specifications issued to potential vendors. The following list is reproduced from a previous EV solicitation to provide an example of potential specifications to include. This list is not exhaustive, and specifics should be added, deleted, or modified to fit your organization's needs.

- Mileage on vehicles shall not exceed 1,000 miles at time of delivery.
- All vehicles shall not be older than one year at time of delivery.
- All vehicles shall be dedicated electric driven compact / sub-compact 4-door sedans with on-board battery chargers.
- All vehicles shall be Level I and Level II charge capable.
- Some vehicles shall be DCFC capable.
- All vehicles shall have a Level I charge cord included with vehicle.
- All vehicles shall be programmable to charge at specific times of the day.
- All vehicles shall be capable of attaining a minimum of 65 mph with a minimum manufacturers estimated range of 70 miles.
- All vehicle passenger compartment volumes shall be a minimum of 85 cubic feet for sub-compact vehicles and a minimum 100 cubic feet for compact vehicles, with a passenger capacity of 4 adults.
- All vehicles shall comply with all current Federal Motor Vehicle Safety Standards and Regulations to safely operate on all U.S. highways and public roads.
- All vehicles shall be licensed, insured, and inspected as required to meet all local laws and regulations.
- All vehicles shall have government license plates installed prior to delivery.
- All vehicles shall be registered in the state.
- All vehicles shall be equipped with air conditioning, AM/FM radio, front and back seat belts (one for each passenger), power windows and door locks, power steering, supplemental restraint system (SRS) for all passengers, automatic transmission, automatic traction control, anti-lock brake system, A/C brushless drive motor, J-1772 charging coupler, tire pressure monitoring system, spare tire, jack, and complete set of tools for changing a flat tire.

[14] http://naftccourses.wvu.edu/?page_id=113 or http://naftccourses.wvu.edu/?page_id=115

## Vehicle Utilization Standards

The higher upfront cost of EVs is offset by the long-term financial benefit of lower operating costs, like reduced fuel and maintenance costs. As described in the F4F companion document, *Fleet Transition Planning for Alternative Fuel Vehicles*, minimum vehicle utilization standards maximize the return on investment by increasing the mileage per vehicle. Consolidating miles onto a lesser number of new vehicles is a good way to reduce costs, streamline the fleet, and ensure fleet managers maximize their investment.

During pre-deployment due diligence, determine the baseline miles per year per vehicle, and then determine what this number needs to be in order to justify the purchase. Without incentives, an EV will likely need to drive more than 12,000 miles per year to achieve payback within the useful life of the vehicle. For fleets that can take advantage of federal and local tax incentives, the payback on a vehicle driving 12,000 miles per year should be much lower. The more gasoline miles transitioned to electric miles, the faster the fleet can expect to see a return on the investment.

## Data Requirements for Ongoing Program Management

In order to contribute to evidence-based fleet management, fleet managers should implement a fleet management information system (FMIS), which tracks fleet inventory data and usage data, including mileage, fuel use, costs, and other information necessary for optimal management.[15] These systems may need to be slightly modified to accommodate EV-specific data. For example, instead of tracking gasoline fuel used in the traditional fleet, it will be important to capture new data fields like energy consumed (kWh); the vehicle's state of charge (SOC) before, during, and after trips; charge times; durations; and the associated increase in SOC.

Additionally, many fleets use telematics and GPS devices to monitor the location, movements, status, and behavior of fleet vehicles. Telematics services are available from dozens of commercial vendors for a variety of fleet applications at a range of price points, but telematics with EV-specific functionality remains a nascent, niche offering.

Whatever the chosen technology solution, the goal is ongoing data-driven program management that tracks vehicle use and performance. This data should be used to establish baseline performance and metrics for improvement, as well as monitor progress regularly.

# Conclusion

The benefits of deploying EVs in fleet applications can be numerous, from reduced petroleum use and greenhouse gas emissions to lower fuel and maintenance costs. As with any transition to a new technology, the process comes with notable changes. By following the lessons learned and best practices established by adopters of EV, any fleet can ensure the successful integration of EVs into their fleet operations. This step-by-step, evidence-based decision-making process will help fleet managers: determine whether their fleet is suitable for EV transition, select appropriate applications, and maximize their fleet's potential.

[15] http://www.acq.osd.mil/pepolicy/fleet/fleet_FMIS.html

# Appendix A: Addressing EV Misconceptions

## *Electric vehicles have enough range to support the vast majority of driving needs.*

Range anxiety, or the fear that an EV's battery does not have enough capacity to fulfill all of the miles needed by a driver during the course of a day, is an oft-cited barrier to wider adoption of EVs. There is ample evidence to the contrary: nearly 90% of everyday driving[16] can be served by an EV. The average U.S. commuter drivers 37 miles per day, which is well within the range of most available EV models. The number of EV models across light-duty use classes has steadily increased in recent years and we can expect that as battery technology improves this trend will continue and ranges will increase.

## *Electric vehicles are becoming cost effective in many applications.*

Many EV models cost more to purchase outright; however, there are numerous additional factors that can make EVs cost less than an internal combustion engine (ICE) vehicle over the life of the vehicle. First and foremost are the availability of federal and state tax credits that will reduce the upfront purchase costs. The current federal tax credits vary based on the size of a vehicle's battery and are limited to $7,500 per vehicle.[17] State tax credits vary from state to state in both structure and monetary value, but are not available in all states. The U.S. Department of Energy maintains a database of both federal and state credits on the Alternative Fuels Data Center.[18]

Additionally, EVs cost significantly less to operate than ICE vehicles. The average fuel cost of an ICE vehicle is approximately 8-12¢ per mile, while using electricity to drive an EV costs 3.5¢ per mile on average.[19] PHEVs tend to have similar maintenance cycles as an ICE since they also have an ICE engine in addition to the battery engine. BEVs on the other hand typically require little to no regular maintenance, there are fewer fluids to change, and far fewer moving parts relative to conventional gasoline vehicles. Brake wear is also reduced significantly due to regenerative braking.

EVs that replace old and inefficient vehicles are most likely to yield an attractive return on investment.

## *Charge times are decreasing.*

The amount of time needed to charge either a PHEV or a BEV depends on the size of the battery as well as the state of charge. The personal driving habits of the user will also impact charge times since a full charge may not always be necessary in order to complete a trip. Level 1 charging is the slowest, adding 2-5 miles of range per hour of charging, and is best suited where a vehicle sits for long periods overnight or during the middle of the workday. Level 2 charging is the most common charging infrastructure available publicly and typically adds 10-20 miles of range per hour of charging. DC Fast Chargers are growing in availability, and can add 50-70 miles of range in an hour of charging. EV drivers can reduce charge times by knowing that a full charge is not always necessary to complete a trip and therefore charging only long enough to get 'home'. Another strategy to reduce charge times is called 'opportunity charging' whereby a driver will charge the vehicle for some time when proximate to charging infrastructure but not necessarily in need of a charge.

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[16] The most recent example was published by a group of researchers at MIT on 8/15/16 in Nature Energy: Potential for widespread electrification of personal vehicle travel in the U.S..
[17] https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d
[18] http://www.afdc.energy.gov/laws
[19] EV costs calculated using an efficiency of 29kWh/100 miles and a national average for electricity prices of $0.12 per kilowatt hour. ICE vehicle costs calculated with an EPA estimated 31 MPG combined city/highway at costs of $2.50 to $3.90/gallon.

## *Selection is increasing.*

Presently, the sedan class constitutes the bulk of vehicles available as EVs. In Model Year 2016 there were 11 different BEV models and 15 different PHEV models.[20] Model Year 2017 will see an increase in the available vehicles in this class, but there remain few, if any, offerings in Sport Utility Vehicles or Light Pickup trucks. Some manufacturers have been working towards EV offerings in that vehicle segment, although they are not widely available. Beyond the light-duty sector, the number of medium- and heavy-duty vehicles is growing, but they are presently characterized by niche manufacturers working to establish scalable supply chains and vehicle availability.

## *EVs are high-performing.*

Electric vehicles offer exceptional torque and rapid acceleration. For example, the 310 kWh Tesla Model S Performance accelerates from 0 to 60 MPH in 3.9 seconds, which is the same time as a 2014 Porsche 911 Carrera S.

## *Cold weather reduces the performance of all vehicles, but EVs still perform well.*

Unfortunately, cold weather reduces the performance of all vehicles. According to fueleconomy.gov the efficiency of an ICE vehicle operating in an urban environment will experience about 12% lower fuel economy at 20°F than it would at 77°F. The impact on EVs can be worse, where they may experience more than a 30% reduction in efficiency. However, even after this lost efficiency, a Nissan Leaf, for example, would still be operating at the equivalent of 80 MPG at 20°F.

## *Regardless of electricity source, EVs tend to emit fewer greenhouse gases.*

The mix of electricity generation sources in the U.S. can vary significantly from region to region, meaning that the GHG emissions impact of driving an EV varies. Emissions are the sum of the emissions produced at the tailpipe and the upstream emissions produced in order to get the fuel to the vehicle. Relative to other transportation fuels, EVs may emit more GHGs from upstream sources; however, since they do not emit tailpipe emissions when operating on the electric motor, the overall 'well-to-wheels' emissions of EVs will be lower than gasoline vehicles in nearly every instance. For more information, refer to Argonne National Lab's study of the relative GHG emissions of EVs versus ICE vehicles, which found that in almost all scenarios EVs produced fewer total emissions than ICE vehicles, with the exception of the most coal-dependent regions, where the emissions from EVs were similar to those from ICE vehicles.[21]

## *EV batteries should be disposed of responsibly.*

As with any battery or vehicle component, the manner in which EV batteries are disposed of will influence their impact on the environment. Widespread battery recycling will eventually minimize the life-cycle impacts of EV battery disposal, but since electric drive vehicles are still relatively new to the U.S. and there is not a large supply of used batteries, it remains to be seen what practices will be most common for recycling the batteries. Given that consumers who purchase EVs are often motivated by the environmentally-friendly nature of these vehicles, it is plausible that consumers will seek out reputable entities to dispose of batteries in a responsible way. As the EV market matures, so too will the battery recycling market to support post-consumer batteries. Many of the major OEMs have announced plans to repurpose old EV batteries for applications such as distributed energy storage on the electric grid, which can backup intermittent power sources such as wind and solar.

[20] http://www.afdc.energy.gov/vehicles/search/
[21] http://www.afdc.energy.gov/pdfs/argonne_phev_evaluation_report.pdf

# Appendix B: Public and Private Fleet Electrification Case Studies

The following examples highlight successful EV deployment programs across a variety of fleet types and vehicle applications.

SAFE: Transitioning Municipal Fleet to Alternative Fuel Vehicles
http://www.greenhoustontx.gov/ev/Houston_Case_Study_2013.pdf
*In this study, the Electrification Coalition examines how the City of Houston electrified its fleet to the point at which EVs now constitute over 50% of its light-duty fleet.*

Pacific Gas and Electric, Electrification Coalition, 2012
http://fleetanswers.com/sites/default/files/PGE_case_study_Final.pdf
*The Electrification Coalition outlines the implementation of electric vehicles into Pacific Gas and Electric's large and flexible fleet.*

AF Tests All-Electric Vehicle Fleet, US AIR FORCE, 2014

Case Study on Electric Vehicles, Durham, North Carolina fleet, 2014 https://nccleantech.ncsu.edu/wp-content/uploads/PEV-Case-Study2.pdf
*The City of Durham, North Carolina describes their transition from gasoline-powered vehicles to EVs in wake of their 2007 Climate Action Plan.*

Plugged in Fleets, The Climate Group, 2012
http://www.theclimategroup.org/_assets/files/EV_report_final_hi-res.pdf
*The Climate Group offers a comprehensive guide on the best practices for deployment of electric fleet vehicles.*

Electric Car Fleet, Chivas Brothers, 2012
*Scotch whiskey and premium gin business Chivas Brothers provides a case study of how they used carpooling and electric vehicles to transform their fleet.*

City of Loveland fleet, Electrification Coalition, 2012
http://fleetanswers.com/sites/default/files/Loveland_Case_Study_092613.pdf
*The Electrification Coalition's case study on Loveland, Colorado displays how the city and its partners helped make Northern Colorado a hub for electric vehicle fleet adoption.*

FedEx Case Study, Electrification Coalition, 2012
*FedEx discusses the lessons they learned and the key takeaways from EV deployments on a global scale.*

Nova Scotia fleet. The Clean Foundation, 2015
http://clean.ns.ca/wp-content/uploads/2014/09/Municipal-Fleet-case-study-pdf.pdf
*The Clean Foundation outlines their 'Municipal Fleet Initiative,' which serves to equip municipalities in Nova Scotia with the tools for EV fleet deployment.*

Fleet Electrification Roadmap, Electrification Coalition, 2009
*The EC provides a public policy guide to transforming the U.S. light-duty ground transportation system from one that is oil-dependent to one powered almost entirely by electricity.*

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