Electric Drive Fleet Applications

Notes

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Introduction

There are many options available for fleet managers who wish to convert their fleets to alternative fuel vehicles. The previous section provided an overview of alternative fuel options and their benefits and drawbacks. This section will provide information specific to the use of electric drive vehicles as a fleet option.

Electric drive vehicles are available in many forms for both light-duty and heavy-duty applications. Charging stations are available to the public. There are three main options for at-home or at-work charging of fleet vehicles. Electric drive vehicles and their variations have been available for years and the market for such advanced vehicles continues to grow.

The goal of this section is to provide the information necessary for fleet managers to determine if using electric drive vehicles is a viable alternative for their fleet.

Objectives

- Explain how to implement green fleets
- Learn about incentives for converting to electric drive vehicle fleets
- Learn about the availability and cost of operating electric drive vehicles
- Identify the advantages of using electric drive vehicles
- Understand how to safely charge and operate electric drive vehicles

Greening of Fleets

There can be challenges to starting a green fleet, or converting an existing fleet to the use of alternative fuels. According to some industry experts, a successful plan to reduce fuel consumption and carbon emissions requires a long-term vision, incremental change, support from top management, and flexibility to make changes along the way.

There are compelling reasons *why* fleets should be green and deliberate steps on how to implement alternative fuels.[1]

Why Use Green Fleets?

- **Reduce operating costs** by improving efficiency, reducing lifecycle costs, and reduce vulnerability to volatile fuel prices.
- **Reduce greenhouse gas emissions** by implementing the use of electric drive vehicles, which are the primary source of greenhouse gases and urban air pollution.
- **Improve corporate image** by branding business strategies and appealing to public concerns about energy conservation and ecological sensibilities.

How to Implement Green Fleets

- **Get buy-in** from all management and staff levels, and be sure to communicate information about the benefits, goals, and targets frequently.
- **Create long-term objectives** and tangible goals based on best practices in the industry (such as baselines, benchmarks, and progress reports).
- **Avoid setting reduction goals in absolute numbers** for growing fleets or fleets just starting because absolute goals can impede growth.
- **Anticipate obstacles**, such as driver resistance, lag time between original equipment manufacturers' technology and market availability, and slower return on investment.
- **Move slowly** and implement change over time.
- **Improve vehicle use** with selection analysis and education of drivers.
- **Track and report progress** and share successes with employees, shareholders, and the public.

Electric Drive Vehicle Fleets

Electric drive refers to vehicles that use electricity to either power or improve the efficiency of a vehicle. According to the Alternative Fuels Data Center (AFDC), the electricity that is used to power the vehicle may be provided by the electric power grid and is stored in the vehicle's batteries. However, onboard generation of electricity is common in some EVs.

The U.S. Department of Energy (DOE) groups electric drive vehicles into three categories: hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and all-electric vehicles (EVs) that use an energy storage device, such as batteries, to store electricity for use by the electric motor. Battery-powered electric vehicles (BEVs) are advanced technology vehicles that use rechargeable batteries as the only source of energy for the vehicle. They do not require a fuel, such as gasoline or natural gas. Instead, they need to be plugged in to the electrical power system (grid) for charging. There is an additional form of EV in fuel cell electric vehicles (FCEVs). These vehicles typically utilize onboard hydrogen along with polymer exchange membrane (PEM) fuel cells for the onboard generation of electricity. Of all EVs, FCEVs are the only version not widely available for consumer or fleet applications at this time, although lease demonstrations are available.

While the premise behind electric vehicles is basically the same, and they all do possess electric motors and energy storage systems, the way they are designed and their purposes are very different. Fleet managers should consider their driving needs to help determine which EV is right for their situation.

Notes

HEV

Hybrid electric vehicles (HEVs) are the most common of electric vehicles. These vehicles have an internal combustion engine (ICE) alongside one or more electric motors, and typically run on conventional or alternative fuels. This vehicle is aptly named because it is a hybrid between the two technologies. An HEV uses more than one power system, combining an ICE with an electric motor and one or more power sources, such as gasoline for the ICE and batteries for the electric motor.

HEVs receive greater fuel economy than conventional vehicles, but less than the MPGe (miles per gasoline gallon equivalent) of other electric vehicles. HEVs may be fueled at conventional fueling stations and may travel any distance (provided fueling stations are available). However, the all-electric range of these vehicles is usually limited. HEVs do not have a plug-in battery; instead they charge the onboard battery using regenerative braking and the ICE. Energy from the battery provides extra power during acceleration.

The electric motor that helps to drive the wheels is referred to as the "motor/generator" (MG) or as "the traction motor." The MG also captures energy that is normally lost during breaking by using the electric motor as a generator and returning the energy back to the battery. The DOE highlights that HEVs combine the benefits of high fuel economy and low emissions with the power of conventional vehicles (see **Figure 1**).

Figure 1: *Hybrid commercial fleet vehicles. Source: NAFTC.*

PHEV

Plug-in hybrid electric vehicles (PHEVs) are similar to regular HEVs. In fact, most PHEVs are modified HEVs. PHEVs have extra battery capacity when compared to HEVs and have the ability to charge by plugging in their batteries (see Figure 2). When running in EV mode (only on electric power), PHEVs have greater MPGe than HEVs. When out of battery range, PHEVs have similar MPG and range as HEVs.

BEV

Figure 2: *Toyota Prius, a popular plug-in hybrid electric vehicle. Source: NAFTC.*

Battery electric vehicles (BEVs) are the simplest of electric vehicles by design. These vehicles typically consist of little more than batteries and motors in their drivetrains. BEVs receive almost double the MPGe of an HEV, or about three times the MPGe of a conventional vehicle. BEVs can be charged through charging stations by being plugged in for 30 minutes to 12 hours, depending on the charging equipment and initial state-of-charge of the batteries. These vehicles are the least expensive to run of all vehicles currently on the road. However, they suffer from limited battery range, as they do not have an internal combustion engine or generator to charge them. Most BEVs can travel a distance between 50 and 200 miles, depending on the vehicle, weight, and driving conditions. These vehicles are common in fleet applications that require local operation of equipment or predetermined, common routes such as buses (see **Figure 3**).

Figure 3: *The Proterra BEV transit bus. Source: Proterra.*

FCEV

Fuel cell electric vehicles (FCEVs) represent the most advanced technology available for electric drive vehicles. Most use hydrogen gas to power the fuel cell that generates electricity (other fuels are being researched). Electrical power then propels the vehicle. FCEVs do not require such large batteries – this greatly reduces the weight of the vehicle. FCEVs (see **Figure 4**) have a fuel cell and fuel storage tank that will generate electricity on demand for the vehicle. They offer similar MPGe to BEVs, but with the range of HEVs. Some of these vehicles use onboard reformation with fuels such as methane (CH_4) to produce onboard hydrogen (H_2).

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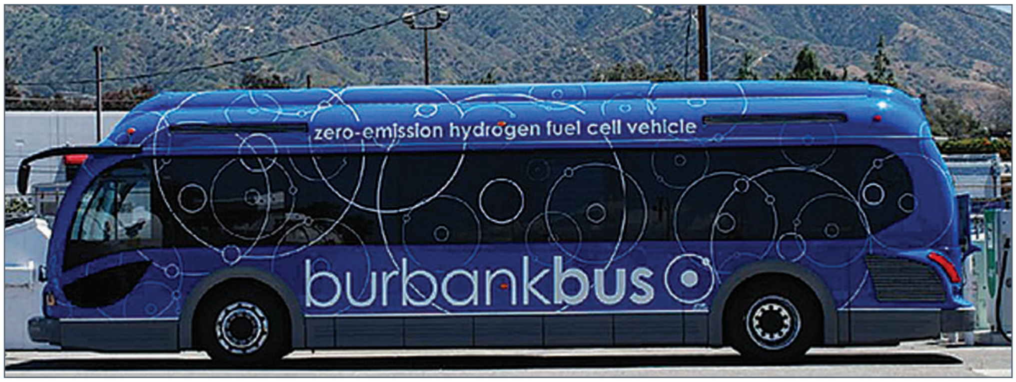

Figure 4: *Hydrogen fuel cell bus. Source: NREL.*

Incentives for Using Electric Drive Vehicles in Fleets

Incentives propagate the growth and purchasing power within organizations that are needed for strong commercial markets. Incentives include partnership initiatives and pooled resources, financial subsidies, and informational tools. The following section discusses incentives available to fleet managers that augment efforts to implement use of electric drive vehicles in their fleets.

Recent industry surveys have confirmed that fleet operations are voluntarily purchasing alternative fuel vehicles to meet specific EPAct regulations and mandates by the federal government. Unfortunately, alternative fuel and advanced technology vehicles cost more than their gasoline-fueled counterparts, and determining how to pay for these more expensive vehicles has become a growing concern for fleet managers across the country. There is however, financial help available.

> ***Did You Know?***
>
> Argonne National Laboratory developed a graphical user interface-based calculator called AirCRED that calculates air pollutant emissions based on specific fleet variables. These emissions "credits" are used to determine excise tax credits.
>
> *To learn more, visit:*
> *www.transportation.anl.gov/modeling_simulation/AirCred*

Despite the fluctuating economy and budget woes, there are a record number of grants and incentives for funding alternative fuel vehicles that have been made available. For example, in 2009, the U.S. Department of Energy (DOE) made nearly $300 million of American Reinvestment and Recovery Act (ARRA) funding available through the Clean Cities program. This single grant funding opportunity is responsible for putting more than 9,000 alternative-fuel and energy-efficient vehicles on the road and establishing 542 fueling stations across the country.

Tax Incentives

In the past decade there have been many federal and state tax incentives for alternative fuels and advanced technology vehicles. For example, a tax credit is available for the cost of LPG fueling equipment placed into service after December 31, 2005. The credit amount is up to 30% of the cost, not to exceed $30,000, for equipment placed into service in 2011. Other major tax incentives included the alternative fuel excise tax credit. Incentives and legislation change on a yearly basis so it is best to check often for updates and changes.[2]

Tools to Help!
Every state has some form of tax credit or rebate for using alternative fuels.
To find state-specific tax incentives, visit: *www.afdc.energy.gov/afdc/laws/search*

Federal Grant Funding

When it comes to grant opportunities, the federal government is by far the largest and most consistent source of funding. Many federal agencies offer funding opportunities, but the majority of funding for alternative fuel vehicles and transportation related projects comes from a handful of federal agencies, such as the U.S. Department of Energy (DOE), Department of Transportation (DOT), Environmental Protection Agency (EPA), and U.S. Department of Agriculture (USDA). These agencies have information on their funding opportunities available on their respective websites.

State Grant Funding

Many states have developed aggressive grant funding programs during the past few years. While each state has different grant funding sources, the designated State Energy Office (SEO) is typically the largest alternative fuel vehicle grant funding source in each state. To make it easy to identify each state's SEO, the National Association of State Energy Officials (NASEO) publishes a directory of State Energy Offices online. The DOE's Alternative Fuels Data Center (AFDC) also publishes an interactive web-based map that allows users to click on any state in the country to get information on alternative fuel vehicle incentives and funding sources.[3] There is a multitude of state-level funding programs for clean air vehicle and transportation projects, but visiting the NASEO and AFDC websites will provide the starting points for any fleet manager interested in state-level funding programs.

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Incentives for Electricity Production

U.S. electricity is domestically produced — a major incentive when considering how to produce EV power. Another attraction is the ability to generate clean electricity from solar, wind, and hydraulic power sources. Demand and production increases will yield more electric grid capabilities, job opportunities, and economic benefits.

Most states and the federal government offer incentives for the purchase of EVs and FCEVs. HEVs and PHEVs are a stepping stone in the EV evolution. They can assist in technology developments while offering the reliance of onboard liquid fuels and some of the benefits of electric-only vehicles. As the EV and FCEV markets expand and develop the required infrastructure of at-home and public charging stations will continue to increase the demand for electricity use for the purpose of transportation.

To learn more about the tax incentives specific to vehicle types in each state, visit:
www.afdc.energy.gov/afdc/laws/search

Electric Drive Vehicle Availability and Cost

The Alternative Fuels Data Center (AFDC) reports more than 6,800 public charging stations nationwide as of 2012. California leads with more than 1,000 statewide. According to the *Clean Fleet Report*, use of EVs is expected to reach 3.2 million by 2015, and "more than 4.7 million EV charge points will be installed globally." **Figure 5** shows the number of stations available per state (not specific to charging level).[4]

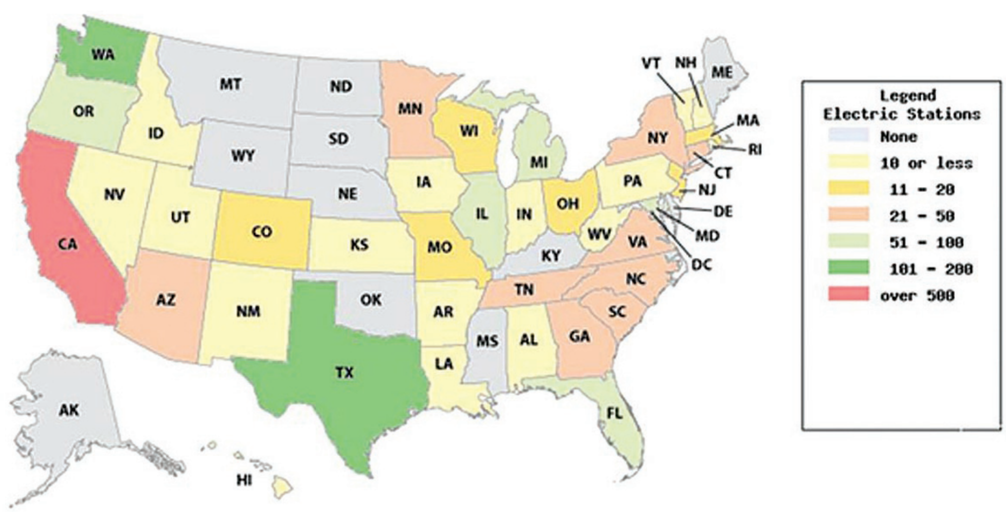

Figure 5: *Public charging stations across the country. Source: AFDC.*

Time frames for a network of recharging stations vary by location. Washington, Oregon, and California are working together to provide a network of charging stations along the Western Seaboard, while Tennessee, Georgia, and North Carolina are trying to establish routes on the East Coast. A network of charging stations would provide infrastructure on major highways located within the driving range of EVs. The EV Project, conducted by Ecotality, is building 14,000 Level 2 charging stations and 400 DC fast-charging stations in six states and in Washington, D.C., with the goal of providing a charging network that connects 18 major cities.[5]

ARRA included $2.4 billion for battery and electric drive component manufacturing, and for electric drive demonstration and infrastructure. Over the next few years, the industry will produce enough batteries and components to support 500,000 PHEVs and HEVs, and by 2015, the U.S. will have the capacity to produce 40% or the world's advanced batteries.[6] One major limitation to establishing an interstate network is the number of EVs on the road. As the number of EVs in use continues to grow, the demand for infrastructure will increase. There are more than 500 charging stations in California and at least 200 in Washington and Texas. As EV usage becomes more prevalent, new sites are being developed across the country.

Other solutions exist for fleet managers including purchasing at-home or onsite charging stations. There are three levels of charging that are discussed in the performance and safety section.

Cost

A key factor in measuring the price of using electricity to power vehicles is the cost of producing electricity and installation of the charging infrastructure. As the technology for installing electric vehicle supply equipment (EVSE) and storing power in electric vehicles becomes more efficient, the cost at the infrastructure and vehicles level should decrease.

EVs provide substantial savings over conventional fuel vehicles for large and small fleets because the cost-per-mile for electricity is lower than conventional fuel. Electricity usage is charged by the kilowatt-hour (kW-hr) and varies based on location and demand. In 2010, commercial electricity prices were significantly lower than the average residential retail price of 11.6 cents per kW-hr, and in some markets, commercial businesses paid between 6.8 and 10.3 cents per kW-hr. Thus, industries pay a price closer to wholesale than residential consumers.[7] Large businesses also can negotiate for lower prices or buy electricity in bulk for additional savings.

The U.S. Department of Energy (DOE) compiled data to show the cost effectiveness of electricity as a fuel. **Figure 6** shows a comparison between gas and electricity cost-per-mile, and the estimated cost of electricity per gasoline gallon equivalent (GGE) (see **Figure 6**).

When the price of electricity is 12 cents per kilowatt hour (kW-hr) an EV that performs at 3 miles per kilowatt hour will cost about 4 cents per mile to operate. By comparison, if gasoline costs $3.50 per gallon, a vehicle that runs at 22 miles per gallon costs about 16 per mile to operate. For one 50-mile trip, that's a difference of $6. Over the course of a year a vehicle driving an average of 10,000 miles saves $1,200. For fleet vehicles that accumulate higher annual mileage, the saving is more substantial.

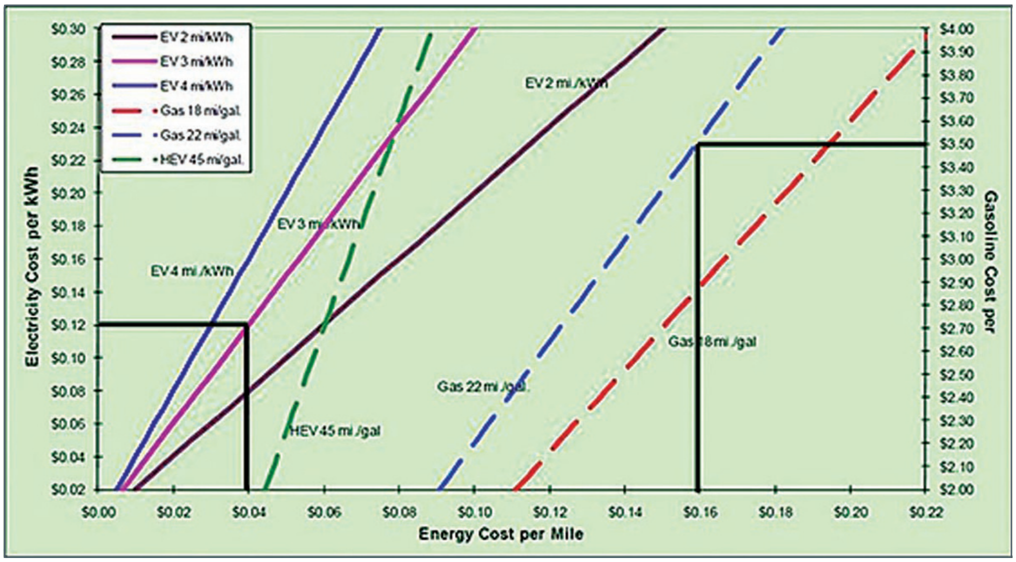

Figure 6: *A comparison of electricity and gasoline energy cost per mile. Source: AFDC.*

The long-term savings of using electric vehicles is apparent. According to the DOE, when the maintenance and repair costs are calculated with fuel cost savings, the average cost per mile to operate an EV is approximately 12.6 cents lower than using gasoline. Another comparison that may be more useful for fleet managers is based on the gallon of gasoline equivalent (GGE) prices (see **Figure 7**). The prices of electricity are based on national average rates for residential electricity. The GGE for electricity is 33.6 kW-hr. When compared to other alternative fuels, electricity price variation is significantly less.

Fuel	Area	2012 Cost	2009 Cost
Gasoline	National Average	$3.37	$1.86
Diesel	National Average	$3.86	$2.44
Electricity	National Average	$3.87	$3.86

Figure 7: *Electricity and gasoline and diesel cost comparison, 2009-2012. Source: AFDC.*[8]

Like all energy sources, costs to produce and use electricity depend on a variety of factors. According to the U.S. Energy Information Administration, the majority of America's electricity is generated from coal, natural gas, and nuclear processes. The cost to build, finance, maintain, manage, and operate the power plants that process the raw materials or nuclear energy into electricity, as well as costs associated with the complex distribution system drive the price of electricity for consumer use.

The availability of coal and natural gas and the cost to process the raw materials used in electricity production play a major role in the price paid by consumers. As availability of raw materials fluctuates, the price of electricity follows suit. The cost to process raw materials also affects electricity cost depending on the type of raw material used and the processing and distribution systems in various locations across the country. The price of electricity increases with seasonal changes as well.

Electric Drive Cost Summary

- *Availability of Raw Materials*
- *Cost to Process Raw Materials*
- *Processing and Distribution Expenditures*
- *Seasonal Weather Effects on Energy Consumption*
- *State and Federal Regulations*

Electric Drive Vehicle Advantages

As with all alternative fuels, there are advantages and things to consider when switching fleets to electric drive vehicles. Each of the four main types also has advantages and things to consider when compared to one another. The following lists cover the four main categories of EVs.

HEV

Advantages:

- Better fuel economy than gasoline/diesel counterparts
- Lower emissions than conventional vehicles
- Combines efficiency of EVs with range of gasoline fuel

Things to Consider:

- Capital cost/purchase price
- Battery life/disposal
- Fuel economy advantages highly dependent upon driving conditions

Notes

PHEV

Advantages:

- Better fuel economy than gasoline/diesel counterparts
- Lower emissions than conventional vehicles
- Combines efficiency of EVs with range of gasoline fuel
- Extended battery-only range when compared to HEVs

Things to Consider:

- Capital cost/purchase price
- Battery life/disposal
- Fuel economy advantages highly dependent upon driving conditions
- More limited availability than HEVs

BEV

Advantages:

- Lower fuel costs
- No localized emissions
- Quiet operation
- At home charging

Things to Consider:

- Capital cost/purchase price
- Battery life/disposal
- Limited driving range
- Limited public recharging stations
- Limited availability when compared to HEVs
- Emissions do occur at fossil fuel power plants used to produce electricity
- Charging time

FCEV

Advantages:

- Lower fuel costs
- No localized emissions
- Quiet operation

Things to Consider:

- Capital cost/purchase price
- Limited driving range
- Limited public fueling stations
- Limited availability
- Emissions and energy required to produce hydrogen for use in FCEVs

Electric Drive Vehicle Performance and Safety

The overall performance and safety of electric drive vehicles are much the same as conventional vehicles. Each type of EV has different performance and safety issues. Main issues of performance and safety deal with the high voltage electric storage systems onboard these types of vehicles. Since the size and complexity of these systems varies with each, their unique issues are discussed in the following section.

Performance

HEVs and PHEVs

The overall performance of HEVs and PHEVS are similar to their conventional vehicle counterparts. These vehicles offer the same options while providing for lowered emissions and fuel savings. They utilize the added benefit of high-torque electric motors for either assisting in or fully powering, vehicles. The driving range is not affected because both versions utilize gasoline engines. Some of these vehicles will have lower power ratings when compared to other vehicles due to overall downsizing to better improve fuel economy. HEVs and PHEVs are available in the light-duty and heavy-duty vehicle sectors. These vehicles typically cost more than conventional counterparts, but have been shown to have lower overall maintenance and operating costs as well as fuel economy savings.

BEVs

The overall performance of BEVs is similar to conventional vehicles. They often have similar or better acceleration. They also have better performance in terms of operating costs since they do not require onboard ICEs or complex transmission systems. In addition to standard transportation vehicles, BEVs are available for niche markets. These vehicles have no localized emissions and are very quiet. This may be valuable when operating in closed spaces where fresh air and sound levels are important. Vehicle performance based on driving range does suffer when compared to conventional vehicles. BEVs are better suited to consistent routes that allow for onsite charging.

FCEVs

The driving performance of FCEVs is also similar to conventional vehicles. These vehicles make a trade-off between the sizes of energy storage systems such as batteries with the required storage for onboard hydrogen. Therefore most FCEVs suffer decreased cargo capacities. This is less noticeable when applied to larger vehicles, such as buses and other fleet vehicles. Most FCEVs are only available through lease programs. However, their demonstration is important in the continued evolution of EVs.

Perhaps the biggest area of concern of vehicle performance is the required downtime to charge PHEVs and BEVs. There are three charging levels. These charging options are summarized in **Figure 8**.

Level	Voltage	Charge Type	Estimated Charge Time
1	120 VAC	Common residential grounded receptacle from source to vehicle's onboard charger.	8 to 30 hours
2	240 VAC	Dedicated 40 amp circuit from source to vehicle's onboard charger.	3 to 8 hours
3	High-voltage (VDC)	Direct current from off-board charger; up to 400 amps.	15 to 30 minutes

Figure 8: *The main levels of charging available for PHEVs and BEVs. Source: NAFTC.*

Light-duty PHEVs that are on the market today typically utilize Level 1 charges, which are simple plug-in devices/cords. These can be used at home or anywhere that standard 120VAC power plugs are available. It should be noted that Level 2 chargers are available (see **Figure 9**). BEVs such as the Nissan Leaf also can be charged with a simple cord that is sold with the vehicle (see **Figure 10**). It should be noted that some plug ends may be different than the usually three-pronged AC plugs on most household appliances. The different plug is often associated with the ability to use higher charging currents.

Figure 9: *Level 2 wall-mount recharging stations. Source: GE Industrial.*

Figure 10: *Nissan Leaf charging cord. Source: NAFTC.*

Figure 11: *Free-standing Level 2 charging station. Source: NAFTC.*

Both light-duty and heavy-duty BEVs more commonly use a Level 2 charging station. These stations may require installation at home locations. These stations need a dedicated 240VAC source with a current rating of 40 amps. Level 2 charges also can be utilized with PHEVs. Level 2 stations can be public, at home (see **Figure 11**), or onsite for fleet operations with multiple vehicles (see **Figure 12**).

Level 1 and 2 charges connect the vehicles to grid power that is alternating current, or AC. These vehicles have onboard power converters that convert AC power to high voltage DC for storage in vehicle batteries. To increase acceptability by reducing charging time, there are Level 3 chargers (see **Figure 13**). These devices are dedicated charging (DC) units. The off-board units require high voltage AC (typically 480VAC) connections. These devices also utilize high currents, on the order of 400 amps for quick charging. These systems convert this high-power AC to DC voltage for direct plug-in charging of the onboard DC batteries. These systems can reduce charging time to a half hour or less. However, they are not commonly available and have higher capital costs when compared to Level 1 and 2 charging. They also require BEVs that are dedicated to this charging method. These systems are valuable for the heavy-duty sector where onboard energy storage is much larger than light-duty applications.

Figure 12: *Level 2 Minit-Charger private fleet charging infrastructure. Source: Minit-Charger.*

Figure 13: *The Blink DC Fast Charger. Source: Blink Network.*

Safety

> **Electric Drive Vehicle Performance Summary**
>
> *Compared to conventional fuel vehicles, EVs offer:*
>
> - *Similar vehicle performance*
> - *Lower operating/maintenance costs*
> - *Quieter operation*
> - *Fewer local emissions*

All EVs that are used for on-road transportation are required to meet the same stringent National Highway Safety Associations (NHSA) and Department of Transportation (DOT) safety standards. The Underwriter's Laboratory (UL) and the Society of Automotive Engineers (SAE) have been working to standardize equipment, assess hazards, secure the supply chain, and manage the risks associated with using electric vehicles. Their efforts have resulted in safer, more efficient charging cables and batteries, models for residential and commercial infrastructure, and improved vehicle designs among other advances. National Electrical Code, Article 625—Electric Vehicle Charging System—sets standards governing electric vehicle supply equipment (EVSE) and infrastructure installation.

Most EVs are equipped with manual high-voltage disconnects. These "switches" are used when the car is serviced to ensure that high-voltage systems are disconnected. This also can be used in the event of a crash. Certain vehicles also contain inertia switches that automatically disconnect all high-voltage systems if the vehicle is involved in a crash.

Color coding is an extremely important part of safety when dealing with any EV. For the most part, high-voltage electrical cables are housed in bright orange insulation (intermediate voltage cables also may be wrapped in light blue insulation). It is extremely important to pay close attention to the location of these cables, and to avoid cutting or compromising any of their insulation.

Most PHEVs use the same bright orange or light blue insulation as HEVs. However, since these vehicles are plugged directly in to a power source, there may be more of these cables. Caution should be taken when any of this insulation has been compromised, and any repairs or maintenance should be done by a trained professional. Care should also be taken when recharging PHEVs. These vehicles may only use Level 1 charging stations, which means the vehicle will use a standard three-prong connection but still have the ability to shock, as with any common household AC appliance.

As with HEVs and PHEVs, high-voltage electrical cables in BEVs are housed in either bright orange or light blue insulation. Extreme care should be taken if any of these cables are visible.

Electric Drive Vehicle Safety Summary

- *Safety measures in charging stations*
- *Meet NHSA and DOT standards*
- *High voltage cables are color coded*
- *Maintenance should be done by trained technicians*

Unlike the PHEV, BEVs can use three different charging levels. Depending upon the level, a different voltage will be used. Levels 2 and 3 require that owners install specialized equipment in their homes. This installation should be done by a trained professional. Owners should take care to ensure that their vehicle is charging correctly, and any abnormalities should be reported immediately.

Summary

This material developed an understanding of electricity as an alternative fueling option for fleet managers and explains how to green fleets with electricity and incentives to implement its use. Additional analysis describes the cost, advantages, and performance of electric vehicles. There are four main classifications of EVs: HEVs, PHEVs, BEVs, and FCEVs. Each of these types has their own advantages and things for fleet managers to consider when converting fleets to electric drive vehicles. While there are limited public charging stations, there are multiple options for consumers and fleet managers for at home charging of EVs. As battery technology evolves and more EVs are purchased the demand for public charging stations will increase. As stations become available and battery technologies evolve the overall driving range of EV fleets will continue to grow.

Test Your Knowledge

1) List the four types of EVs presented for fleet managers in this section along with their acronyms.

2) **True or False:** The GGE equivalent price of electric has remained nearly unchanged between 2009 and 2012.

3) The fastest EV charging requires a Level (1, 2, 3) charger.

4) **True or False:** EVs must be charged by only trained professionals due to electric shock hazards.

Answers: 1) Hybrid electric vehicles (HEVs), Plug-in electric hybrid vehicles (PHEVs), Battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs); 2) True; 3) 3; 4) False — while EVs should not be serviced without proper training, standardization and safety features allows for the safe and easy charging of EVs by their owners.

Resources

Electric Drive Vehicle Battery and Component Manufacturing Initiative

The American Recovery and Reinvestment Act (ARRA) of 2009 provided $2 billion for the manufacturing of batteries and electric drive components. In August 2009, DOE awarded grants to 30 recipients. 75% of the investment will support the production of batteries and battery components by U.S. manufacturers as well as a lithium-ion battery recycling project. U.S. manufacturers of electric drive-train components, including motors and power electronics, will receive the remaining funds. This program will lead to at least $4 billion in investments because grant recipients must match the government's contribution. The link below shows companies that were awarded funding from this initiative and gives a summary of the technology being developed and researched.

Learn more about the ARRA:
http://www1.eere.energy.gov/recovery/pdfs/battery_awardee_list.pdf

- **Alternative Fuels Data Center** – Electricity (http://www.afdc.energy.gov/afdc/fuels/electricity.html) – Offers publications about the use of electricity as a fuel, charging locations, and other helpful information about electric drive vehicles.
- **Alternative Fuels Data Center** – Hybrid and Plug-In Electric Vehicles (http://www.afdc.energy.gov/afdc/vehicles/electric.html) – Presents information specifically about hybrid and plug-in electric vehicles.
- **Argonne National Laboratory** (http://www.transportation.anl.gov/batteries/) – Presents research and development on advanced lithium battery technologies as it relates to electric drive vehicles.
- **Clean Cities 2012 Vehicle Buyer's Guide** (http://www.afdc.energy.gov/afdc/pdfs/51785.pdf) – Offers model-specific information about vehicles that utilize alternative fuels.
- **Clean Fleet Report** (http://www.cleanfleetreport.com/) – Provides up-to-date news and research related to electric drive vehicles and infrastructure.
- **Department of Energy Efficiency & Renewable Energy** - HEVs (http://www1.eere.energy.gov/vehiclesandfuels/technologies/systems/hybrid_electric_vehicles.html) – Contains information about the current state of HEVs, the key components of HEVs, and the future of the vehicles.
- **Electric Auto Association** (http://www.electricauto.org/) – Presents current industry headlines, promotes experimentation with EVs, and organizes EV-related gatherings.
- **Electric Drive Transportation Association** (http://www.electricdrive.org/) – Includes information and news on the latest electric vehicles and the electric vehicle market
- **Fuel Cell & Hydrogen Energy Association** (http://www.fchea.org/) – Contains links and resources to help bring fuel cell and hydrogen technologies to the forefront.

- **Fuel Economy** (http://fueleconomy.gov) – Official U.S. government source for information pertaining to the fuel economy ratings and fuel efficiency.
- **Green Car Congress** – Electric (http://www.greencarcongress.com/electric_battery/index.html) – Provides information on topics associated with EVs and their development within the marketplace.
- **Green Car Magazine** (http://www.greencarmagazine.net/) – Contains information about the latest developments in electric drive vehicles
- **Plug In America** (http://www.pluginamerica.org/) – Offers reasons to switch to electric drive vehicles and actions to take to increase electric vehicle usage.
- **The Electrification Coalition** (http://electrificationcoalition.org/) – Presents information about how to advance the acceptance of electric vehicles and reduce the nation's dependence on petroleum.
- **U.S. Department of Energy (DOE)** (http://energy.gov/) – Agency that helps ensure America's security and prosperity by addressing energy-related problems with emerging technologies.
- **U.S. Department of Energy (DOE) Vehicle Technologies Program** (http://www1.eere.energy.gov/vehiclesandfuels/) – Develops more efficient transportation technologies that help reduce domestic dependence on foreign petroleum.
- **U.S. Energy Information Administration** (http://www.eia.gov/electricity/) – Discusses electricity use and demand statistics in different markets.
- **U.S. Environmental Protection Agency (EPA)** (http://www.epa.gov/) – Agency that acts to protect public health and the environment by writing and enforcing pertinent legislation.

Footnotes

1 Environmental Defense Fund, "Greening of Fleets, A Roadmap to Lower Cost and Cleaner Corporate Fleets," http://business.edf.org/sites/business.edf.org/files/greening-fleets.pdg

2 U.S. Department of Energy, Alternative Fuels Data Center, *Electricity Incentives and Laws*, http://www.afdc.energy.gov/afdc/fuels/electricity_laws.html

3 U.S. Department of Energy, Alternative Fuels Data Center, *State Incentives and Laws*, http://www.afdc.energy.gov/afdc/laws/state

4 U.S. Department of Energy, Alternative Fuels Data Center, *Electric Charging Station Locations*, http://www.afdc.energy.gov/afdc/fuels/electricity_locations.html

5 The EV Project, http://theevproject.com/

6 Blueprint for a Secure Energy Future, Investing in Advanced Vehicle Technologies and Infrastructure, http://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf

7 U.S. Energy Information Administration, Electricity Explained, Factors Affecting Electricity Prices, http://www.eia.gov/energyexplained/index cfm?page=electricity_factors_affecting_prices

8 U.S. Department of Energy, Alternative Fuels Data Center, *Alternative Fuels Price Reports*, http://www.afdc.energy.gov/afdc/price_report.html

Notes

CASE STUDY

Location: San Francisco, CA

Company: Pacific Gas and Electric Company (PG&E)

Study: **Electric Drive Vehicles**

Pacific Gas and Electric Company (PG&E) is a company based in San Francisco, California. As an energy company it directs significant attention to energy efficiency and clean energy options. The company's website offers additional information on the company's community and environmental responsibilities. One of the major changes the company has undergone to reduce its carbon footprint has been the greening of its fleet vehicles. The company has deployed multiple hybrid electric vehicles within its fleet as a solid business model. The company has service vehicles such as bucket trucks, "cherry-pickers", and light-duty fleet cars.

There are three basic types of bucket trucks, says Director of Transportation Services Dave Meisel. The first and least fuel-efficient type is the standard conventional fuel truck that operates the bucket with a hydraulic system powered by the vehicle's internal combustion engine. The second type uses conventional diesel engines for propulsion, but uses an electric system to operate the boom and additional systems such as the truck heating and cooling system when the vehicle is stationary. This type of hybrid system allows for reductions in idle fuel consumption and emissions. The third type is the PG&E 100% electric bucket truck, which are the most fuel-efficient because electric motors power the motor for propulsion and all subsystems.

The PG&E 100% electric bucket truck, configured and manufactured by Smith Electric Vehicles. Photo courtesy of PG&E.

PG&E put its first 100% electric truck on the road this year, as the first U.S. prototype based on a European model. With the help of Smith Electric Vehicles (one of a few electric truck manufacturers in the nation), the PG&E chassis has become the model on which other electric bucket trucks have been designed.

Decision Points

Several factors played into the decision to use electric bucket trucks and light-duty plug-in electric hybrids, not the least of which is fuel cost. From a business perspective, the cost of petroleum-based fuel has increased over the last four years. According to Meisel, the compounded annual growth rate of petroleum fuel was 7.5% in the last 15 years and was 12.5% in the last four years. Comparatively, the growth rate of electricity was 2.8%. "Electricity is much more reasonably priced," Meisel said. The inflationary cost of petroleum fuel is expected to increase, so the PG&E business model is looking toward the future to keep its operating costs reasonably low.

Operation of a plug-in hybrid bucket truck that uses a diesel engine for vehicle propulsion but onboard batteries to power subsystems when stationary. Photos courtesy of PG&E.

Government incentives that provide per-unit rebates for each truck put into service also played a role in the decision-making process. There are many state and federal incentives available for businesses in California that choose to use electric drive vehicles. Incentive rebates were built into PG&E's cost analysis, showing that the trucks would be a good investment.
Though the cost-benefit ratio was the main driving force in the decision, the company also believes it has an obligation to environmentally friendly operations, which has enhanced the company's public image. "Public opinion is important," Meisel said, "but incentives and public image don't change the way we do business. The main decision was based on the cost model that showed the trucks were cost efficient."

Fleet Facts

In total, there are 14,000 alternative fuel vehicles; many of which utilize compressed or liquefied natural gas. However, the fleet also includes its all-electric bucket truck, hybrid electric bucket trucks, an extended range electric pickup truck, as well as 20 Chevrolet Volts. The PG&E electric bucket truck, manufactured by Smith Electric Vehicles, can travel up to 120 miles when the batteries are fully charged. The fleet operates within relatively small regions and the miles driven are low at approximately 450 miles per month per truck.

Both types of electric bucket trucks are plug-ins, as well as the Volts. They are plugged into either Level 2 charging stations at the end of each shift to charge overnight or Level 3 Fast Chargers if the truck is expected to return to service more quickly. Batteries are topped-off daily in case of emergency situations.

QUICK FACTS

Fuel Type: Various versions of plug-in hybrid electric vehicles (PHEVs)

Light-duty Fleet: 20 Chevrolet Volts

Heavy-duty Fleet: Various PHEVs and one 100% electric bucket truck

Miles Driven Annually: 5,400

Estimated Fuel Consumption: 120 miles per 120 kW charge

Break Even on Investment: 6-7 years (not including incentives)

The gross vehicle weight of the bucket trucks is between 16,500 and 26,400 pounds, depending on the specific configuration. Payload can be as much as 16,200 pounds.

Generally, battery life for all electric vehicles continues to improve as technology advances. PG&E has not experienced any problems with battery life or performance, Meisel said, although the trucks have not been in service long enough to know conclusively how long the batteries will last before having to be replaced.

Fuel Supply and Infrastructure

PG&E uses Level 2 and Level 3 charging stations depending on the vehicle. All the trucks are charged in-house when they return to the facility at the end of each shift. The charging procedure is very straight forward and the charging stations have operated without any breakdowns or difficulties, "It's just plug and go," Meisel said.

Director of Fleet Services Dave Meisel (right) and Senior Vice President of Safety and Shared Services Des Bell (left) were in the nation's capital to demonstrate the cost effectiveness and performance of 100% electric bucket trucks in fleets. Photo courtesy of PG&E.

Being an electricity provider has its advantages when it comes to electric infrastructure, but the two main reasons the company uses in-house charging are because trucks are used locally and return to the facility each day, and because public infrastructure does not support the charging requirements for such a large battery capacity. PG&E has installed 50 of its own charging stations in various locations. They also plan to increase the vehicle fleet size, which will be able to use the same charging infrastructure.

Costs

Depending on the particular specifications of an individual truck, the purchase cost is more than conventionally fueled vehicles, but the purchase price is offset by fuel savings. The trucks cost approximately 5% more to purchase (including incentives and rebates), but 8% less to operate for a lifetime net savings that outweighs the initial investment. As mileage increases over the life of the vehicle, the percentage of savings also increases incrementally based on the specific vehicle. According to Meisel, the trucks break-even in about six to seven years.

The low cost of electricity — approximately $0.05 per kW-hr per mile — compares favorably to the current cost of conventional fuels. The conventional fleet vehicles at PG&E use 10 million gallons of fuel each year at a cost of approximately $5 million. Thus, the cost/risk profile (the cost compared to the risk) of using electric vehicles is positive. Operating costs also are offset by less required maintenance.

Maintenance and Satisfaction

Because of the nature of PG&E's business, the trucks must comply with specific inspection regulations; therefore, the man-hour costs for maintenance are similar to conventional trucks.

When it comes to performance, electric trucks are similar to conventional trucks. However, acceleration to cruising speed can take approximately twice as long. There is also a slight difference in top cruising speed, but since most bucket trucks operate locally and rarely need to drive on a freeway, the impact of slightly slower acceleration and lower top cruising speed is minimal.

PERFORMANCE COMPARISON		
Metric	Electric Trucks	Conventional Diesel Trucks
0 – 60 MPH	17 – 18 seconds	8 – 9 seconds
Top Cruising Speed	50 - 60 mph	65 – 75 mph
Average Driving Range	120 miles per charge	200 miles per tank

Data provided by PG&E.

Operator acceptance of the electric trucks has been good, Meisel says. Operators expect smooth and reliable operation, and PG&E has had no problems with boom performance. Plus, since the bucket boom operates on an electric-powered motor with no PTO, there are fewer mechanical breakdowns, which makes truck operators and mechanics very happy.

Summary

Large corporations are constantly looking for ways to maximize the bottom line. Although conventional heavy trucks ultimately win the competition for driving range, speed, and acceleration, electric vehicles can be deployed cost-effectively when operating parameters are considered. When business models and cost profiles are structured to include the cost of electricity, maintenance and repairs, and the future of petroleum-based fuel costs, the benefits of electric vehicles show a clear advantage.

As electric charging infrastructure becomes more widely available and as battery technology continues to improve, electric vehicles can be incorporated into many fleets without changing day-to-day operations.

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