Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles

Final Report

A DHS/Assistance to Firefighter Grants (AFG) Funded Study

Prepared by:
Casey C. Grant, P.E.
Fire Protection Research Foundation

THE
FIRE PROTECTION
RESEARCH FOUNDATION

FIRE RESEARCH

The Fire Protection Research Foundation
One Batterymarch Park
Quincy, MA, USA 02169-7471
Email: foundation@nfpa.org
http://www.nfpa.org/foundation

(This page left intentionally blank)

FOREWORD

Today's emergency responders are facing unexpected challenges as new uses of alternative energy increase. These renewable power sources save on the use of conventional fuels such as petroleum and other fossil fuels, but they also introduce unfamiliar hazards that require new fire fighting strategies and procedures.

Among these alternative energy uses are motor vehicles that utilize electric drive propulsion systems. This study focuses on electric drive and hybrid electric vehicles intended for roadway passenger use, and describes the variety of safety issues that these relatively new vehicles may present involving fire and/or rescue emergency situations either on the roadway or at charging/docking stations (e.g., garages).

The safety of fire fighters and other emergency first responder personnel depends on understanding and properly handling these hazards through adequate training and preparation. The goal of this project has been to assemble and widely disseminate core principle and best practice information for fire fighters, fire ground incident commanders, and other emergency first responders to assist in their decision making process at emergencies involving electric drive and hybrid electric vehicles. Methods used include collecting information and data from a wide range of credible sources, along with a one-day workshop of applicable subject matter experts that have provided their review and evaluation on the topic.

The Research Foundation expresses gratitude to the members of the Project Technical Panel, workshop participants, and all others who contributed to this research effort. Special thanks are expressed to the U.S. Department of Homeland Security, AFG Fire Prevention & Safety Grants, for providing the funding for this project through the National Fire Protection Association.

The content, opinions and conclusions contained in this report are solely those of the authors.

(This page left intentionally blank)

PROJECT TECHNICAL PANEL

Tom Hollenstain
State Farm, ATR - Vehicle Research Facility, Bloomington IL

Stephen Kerber
Underwriters Laboratories, Northbrook IL

Larry McKenna
U.S. Fire Administration, Emmitsburg MD

Barbara Mentzer
IA Electrical Board and Chief of Hartford Fire & Rescue, Hartford IA

Ed Roper
South Carolina State Training Academy and NAFTD, Columbia SC

William Scoble
Westwood Fire Department; Westwood MA

Rodney Slaughter
Dragonfly Communications Network, Corning CA

Curt Varone
NFPA (ret.), Quincy MA

PROJECT SPONSOR

U.S. Department of Homeland Security
(AFG Fire Prevention & Safety Grants)

(This page left intentionally blank)

FIRE FIGHTER SAFETY AND EMERGENCY RESPONSE
FOR
ELECTRIC DRIVE AND HYBRID ELECTRIC VEHICLES

A U.S. Department of Homeland Security
(AFG Fire Prevention & Safety Grants)
Funded Project

Prepared by:
Casey C. Grant, P.E.
Fire Protection Research Foundation
One Batterymarch Park
Quincy, MA USA 02169-7471

THE
FIRE PROTECTION
RESEARCH FOUNDATION

May, 2010

(This page left intentionally blank)

EXECUTIVE SUMMARY

As the use of alternative energy proliferates, the fire service has identified a number of areas of concern with hazard mitigation and emergency response. This includes electric and hybrid electric vehicles, which are introducing new and unexpected hazards to fire fighters and other emergency responders.

The goal of this report is to assemble and disseminate best practice information for fire fighters and fireground incident commanders to assist in their decision making process for handling electric and hybrid electric vehicles. Specifically, this study focuses on vehicles intended for roadway passenger use involving fire and/or rescue emergency situations, either on the roadway or at charging/docking stations (e.g., garages). The project deliverables will be in the form of a written report, which will include best practices that can serve as the basis for training program development by others.

The deliverables for this project collectively review the available baseline information, identify the fundamental principles and key details involving fire/rescue tactics and strategy, provide a summary of core basics, and address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other applicable topics.

A companion study to this report focuses on solar power systems rather than electric and hybrid electric vehicles (*Fire Fighter Safety and Emergency Response for Solar Power Systems*, FPRF). This has taken an identical approach and focuses on assembling and disseminating best practice information for fire fighters and fireground incident commanders to assist in their decision making process. This companion report addresses buildings and other structures with solar power systems that are intended to supply power to the respective structure, with a primary focus on solar photovoltaic panels used for electric power generation.

This overall initiative (consisting of the reports on *Electric Drive and Hybrid Electric Vehicles* and *Solar Power Systems*) is funded through a U.S. Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) Assistance to Firefighters Grant (AFG).

(This page left intentionally blank)

TABLE OF CONTENTS

(This page left intentionally blank)

SUMMARY OF FIGURES AND TABLES

1. INTRODUCTION AND BACKGROUND

Amongst the new challenges facing the U.S. fire service is the changing nature of emergency response to incidents where alternative energy sources are in use. The term *alternative energy* describes any of the various renewable power sources that used in place of conventional fuels such as petroleum and other fossil fuels.[1]

The fire service has identified a number of areas of particular concern with respect to hazard mitigation and emergency response in these scenarios. As the use of alternative energy proliferates, it introduces new and unexpected hazards that confront and challenge responders in an emergency.

Some fire service organizations are in the process of developing recommended emergency response procedures and best practices on a local or regional basis; in other jurisdictions basic information on the hazard and appropriate response is lacking or not currently available. This project will take a comprehensive national look at the needs of the fire service for credible information and best practices in order to address these topics for first responders and provide an overall coordinated perspective on this topic.

The goal of this project is to assemble and widely disseminate best practice information for fire fighters and fire ground incident commanders to assist in their decision making process. Specifically, this study focuses on electric drive and hybrid electric vehicles intended for roadway passenger use, and involving fire and/or rescue emergency situations either on the roadway or at charging/docking stations (e.g., garages). Figure 1-1 provides an example of a plug-in hybrid electric vehicle addressed by this study.

Figure 1-1: Plug-In Hybrid Electric Vehicle
(Photo courtesy of NREL Photographic Information Exchange)

While this report addresses issues of concern on electric drive and hybrid electric vehicles, a separate companion report addresses solar power systems, and specifically buildings and other structures using solar panels with a primary focus on solar photovoltaic panels used for electric power generation. The project deliverables will be in the form of a written report that will include best practices, which can provide the basis for the development of training programs by others.

This report will focus on electric drive and hybrid electric vehicles through the following specific tasks:

1. Collect and analyze applicable scientific studies, case study reports, and available operational and training guidance from various sources;
2. Synthesize this information in the form of best practice guidance for emergency response;
3. Make the project deliverables broadly available to the fire service through online and print methods, and generate awareness of its accessibility; and
4. Determine if standardization of safety practices is feasible and if so disseminate information to those involved, including submittal of possible revisions to applicable codes and standards.

The first of these tasks is key, which is to collect and analyze all applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to electric drive and hybrid electric vehicles. This task included an interactive one-day workshop involving experts on the fire service and other subject matter.

The goal of the one-day workshop is to identify, review, and assemble best practice information for tactical and strategic decision making by fire fighters and fireground incident commanders, to assist in their decision making process when responding to fire and/or rescue emergency events involving electric drive and hybrid electric vehicles, including within structures (e.g., residential garages). The workshop will focus on the following objectives:

- Collectively review the available baseline information provided to participants prior to the workshop;
- Identify the fundamental principles and key details involving fire/rescue tactics and strategy, and provide a summary of core basics; and
- Address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other topics applicable to the overall workshop goal.

2. OVERVIEW OF ELECTRIC AND HYBRID ELECTRIC VEHICLES

Technology offers great advantages that generally make our world a better place. Yet when it fails it can introduce new and unusual challenges for emergency responders. As new types of electric and hybrid electric vehicles proliferate, fire fighters and other emergency first responders need to be prepared to handle the hazards they present.

This section provides the baseline information necessary to understand and adequately address electric and hybrid electric vehicles. This includes a historical review of the technology used for electric and hybrid electric vehicles, clarification of the terms *electric* and *electric hybrid*, a review of marketplace trends, and a summary of currently available vehicles.

History of Electric and Hybrid Electric Vehicles

The concept of using electricity to power an automobile is not new. The first electric powered vehicle is credited to Robert Anderson of Aberdeen, Scotland in 1839.[2] In the early days of the automobile from about 1890 to 1905, electric vehicles were competitively marketed and sold in the U.S. along with internal combustion engine vehicles and steam cars.[3]

The extensive work of the early electrical pioneers like Thomas Edison and George Westinghouse stimulated the development of electric vehicles during this time period, and the limited range of electric vehicles was well suited for the intercity roadway system of the day. But as roadways expanded the relatively short range of electric vehicles became obvious. Soon they yielded to more cost effective internal combustion engine designs. Additionally, these fossil-fueled energy source engines did not require the long recharging times required of their electric vehicle relatives.[4] The era of the internal combustion engine vehicle took hold, and became the vehicular technology leader through the remainder of the 20th century.

For hybrid vehicles, the Pope Manufacturing Company of Connecticut is credited with one of the earliest hybrid prototype vehicle designs in 1898. This was followed soon after by production vehicles in Europe based on a parallel hybrid system design that first appeared at the Paris Auto Show in 1901. The Lohner-Porsche Group in Germany introduced a series hybrid electric vehicle in 1903 using electric motors on the two front wheels. The Lohner-Porsche Chaise is considered among the first front wheeled drive vehicle of its era, and on battery alone it had a range of almost 40 miles.[5]

Soon thereafter the Mercedes-Mixte companies teamed together to create a prototype hybrid electric vehicle. In the United States two well-known electric vehicle manufacturers, the Baker Company and the Woods Company, independently came out with hybrid vehicles in 1917. Ultimately, however, the marketplace did not support the hybrid electric vehicles due to their cost and complexity, and they faded under the domination of the internal combustion engine vehicles as the petroleum-supported infrastructure expanded.[6]

Renewed interest in electric vehicles occurred in the late 1960s and early 1970s as a result of the environmental movement and concerns about air pollution. During this time period the general safety of motor vehicles also took an important step forward. In 1966 the U.S. Congress passed the *Highway Safety Act* and the *National Traffic and Motor Vehicle Safety Act* (Vehicle Safety Act). The Highway Safety Act created the National Highway Safety Bureau (NHSB), which later became the National Highway Traffic Safety Administration (NHTSA). NHTSA is authorized by the federal government to establish U.S. safety standards for motor vehicles.[7]

Concerns over the growing air pollution within major urban areas were part of the motivation for the environmental movement of the late 1960s and early 1970s. Magnifying these concerns were the oil crises of 1973 and 1979, which led to renewed interest in electric vehicle technology. However, the short range and high cost of batteries continued to be insurmountable problems in the marketplace. In 1975 Congress intervened with the *Energy Policy and Conservation Act* (EPCA) that set the goal that cars double their average fuel efficiency by 1985 and cost-effective standards be established for light trucks.[8]

In 1976 the U.S. Congress enacted the *Electric and Hybrid Vehicle Research, Development, and Demonstration Act*, and this provided additional focus on the development of electric vehicle technology. This effort helped to promote advances in hybrid electric components, such as batteries, motors, and controllers, and which led to the development of the technology that continues to be implemented and improved in today's electric and hybrid electric vehicles.[9]

As gasoline and other fuel prices dropped in the early 1980s and remained low throughout the decade, the buying public's desire for fuel economy languished and the marketplace shifted toward utility, performance and luxury. Once again in the early 1990s new concerns arose with the environment (i.e., global warming) and national security based on dependence on foreign oil (i.e., 1991 Gulf War). In response were further key federal legislative initiatives, most notably the *Clean Air Act Amendments* of 1990, and the *Energy Policy Act* of 1992.[10]

Together these legislative initiatives promoted the driving publics use of alternative-fueled vehicles. The Clean Air Act Amendments define alternative fuels as: methanol, ethanol, and other alcohols; reformulated gasoline; reformulated diesel (for trucks only); natural gas; propane; hydrogen; or electricity. The Energy Policy Act addressed these fuels except for reformulated gasoline and diesel, and also defines other alternative fuels derived from biomass, liquid fuels derived from coal, and alcohol blended with other fuels containing at least 85 percent alcohol by volume.[11]

Today's mass-produced hybrids are directly linked to an initiative that started in the fall of 1993 when the U.S. government and American auto industry announced the *Partnership for a New Generation of Vehicles* (PNGV). The goal was to develop an automobile with a fuel efficiency of 80 miles per gallon, and the effort became referred to in the popular media as the *supercar*.

The program's $3 billion investment over nine years resulted in separate prototypes developed by Chrysler, Ford, and General Motors. However, the initiative sputtered because the arbitrary goal of 80 miles per gallon resulted in designs that automakers felt could not be mass produced at a price consumers would be willing to pay.[12]

This activity in the United States spurred Toyota to independently develop the Prius for the Japanese market at more practical fuel efficiencies, and at the same time Honda likewise developed the Insight. In late 1999 Honda beat Toyota to the U.S. marketplace when they introduced the Insight, and today both automakers lead the marketplace with hybrid electric vehicles, with later editions of the Toyota Prius among the favorites of consumers. These vehicles provide the foundation for today's marketplace of electric and hybrid electric vehicles

Today, while electric vehicles are still relatively uncommon compared to conventionally fueled vehicles, it is not unusual to observe a hybrid electric vehicle on roads in the United States. In general, public consumers are becoming more and more aware of hybrids and other alternative-fueled vehicles. Figure 2-1 provides an illustration of the race track pace car used at the New Hampshire Motor Speedway, and this provides a fitting symbol of the growing recognition of hybrids in today's automobile marketplace.

Figure 2-1: Toyota Camry Hybrid Race Track Pace Car

Electric Vehicle Fundamentals

The term *electric vehicle* is commonly heard in today's automobile marketplace. An electric vehicle is one that is powered using electric motors and motor controllers for propulsion, in place of more common propulsion methods such as the internal combustion engine.[13] Electric vehicles are frequently designated by the initials EV, although this is also used to represent emission vehicle designations (e.g., ULEV for ultra-low emission vehicles), which may or may not be utilizing electric propulsion, thus resulting in some marketplace confusion.

Multiple definitions of the term electric vehicle can be found in the common literature and consensus codes and standards. The following are several examples:

Electric Vehicle (EV): A vehicle powered by electricity, generally provided by batteries. EVs qualify as zero emission vehicles for emissions.[14]

Electric Vehicle (EV): A vehicle powered solely by energy stored in an electrochemical device.[15]

Electric Vehicle (EV): An automotive-type vehicle for highway use, such as passenger automobiles, buses, trucks, vans, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. For the purpose of this article, electric motorcycles and similar type vehicles and off-road self-propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like, are not included.[16]

There are multiple variations and subclasses of EVs and the most common are: BEVs (battery electric vehicles); HEVs (hybrid electric vehicles); PHEVs (plug-in hybrid electric vehicles); and NEVs (neighborhood electric vehicles). In addition, extended range EVs refer to EVs that have range comparable to or better than traditional internal combustion engine (ICE) vehicles. All of these vehicles are discussed in subsequent sections of this report, and the following are definitions for these vehicle types:

Battery Electric Vehicle (BEV): An electric vehicle powered primarily by electricity stored in batteries. A BEV is not a hybrid electric vehicle.[17]

Extended Range Electric Vehicle (EREV): An electric vehicle equipped with an electrical generator (powered by an ICE) that supplements the electrical propulsion system and extends the vehicles operating range.[18]

Hybrid Electric Vehicle (HEV): A vehicle powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drive train. See also Electric Hybrid Vehicle.[19]

Neighborhood Electric Vehicle: A four-wheeled battery-operated electric "low-speed vehicle", with "low-speed vehicle" classified by U.S. DOT as having a gross vehicle weight rating of less than 3,000 lbs. (1,400 kg) and a top speed of between 20 to 25 mph (32 to 40 km/h).[20]

Plug-in Hybrid Electric Vehicle (PHEV): Hybrid vehicles that can charge their batteries from an external source in the same fashion as electric vehicles.[21]

A special subclass of an EV is a *neighborhood electric vehicle* (NEV). These are electric vehicles not intended or designed for long distance travel or highway speeds. An NEV is a four-wheeled *low-speed vehicle* that is battery operated and typically recharged on normal residential electrical circuits. A low-speed vehicle is specifically classified by U.S. DOT as one that has a gross vehicle weight rating of less than 3,000 lbs. (1,400 kg) and a top speed of between 20 to 25 mph (32 to 40 km/h).[22] Figure 2-2 illustrates an NEV used for utility purposes.

Figure 2-2: NEV - Neighborhood Electric Vehicle for Utility Purposes
(Photo courtesy of NREL Photographic Information Exchange)

The U.S. DOT classification of low-speed vehicles in 1998 has allowed this type of vehicle to proliferate, and today NEVs are being increasingly used in certain self-contained settings with public roads such as college campuses, federal government installations, and large industrial/hospital facilities. From the standpoint of an emergency responder, the NEVs today often look very similar to a conventional small or compact vehicle. Figure 2-3 illustrates a newer model NEV that looks very similar to the popular gasoline-powered *SmartCar*.

Golf carts and other popular off-road electric vehicles do not qualify as low speed vehicles or NEVs since they do not meet roadway safety requirements. Some of the most fuel-efficient prototype designs are NEVs, and certain designs have already become quite popular in the marketplaces of countries other than the United States.[23]

Figure 2-3: NEV - Neighborhood Electric Vehicle for Passengers
(Photo courtesy of State Farm Vehicle Research Facility)

Vehicles are generally grouped into two broad categories: *Highway* and *Non-Highway* (a.k.a. *Other*). Highway or roadway vehicles include any vehicle designed to operate normally on public highways and roadways, such as automobiles, motorcycles, buses, trucks, and trailers. These do not include, for example, farm vehicles, construction vehicles, trailers such as mobile homes mounted on foundations, all-terrain vehicles not intended for roadway use (e.g., ski area maintenance equipment), trains, boats, ships, and aircraft.

This project addresses passenger roadway vehicles, and has a specific focus on passenger automobiles. While it does not exclude motorcycles, buses, trucks, and trailers, they are included only to the extent that they further clarify the objectives of this project to assemble best practice information for fire fighters and fireground incident commanders to assist in their decision making process. This study generally excludes off-road vehicles, and focuses primarily on electric cars and/or electric automobiles used to transport people.

Passenger vehicles, or automobiles, are categorized into six different size classes as established by the regulations from the U.S. Environmental Protection Agency. These are summarized in Table 2-1, Size Classifications of Automobiles.[24] Vehicle size classifications are different from vehicle styles, which are based on descriptive terms such as sedans, coupes, hatchbacks, sports-utility vehicles, minivans, etc…

Table 2-1: Size Classifications of Automobiles[25]

Class	Description
Minicompact	Less than 85 cubic feet of passenger and luggage volume
Subcompact	Between 86 to 100 cubic feet of passenger and luggage volume
Compact	Between 101 to 110 cubic feet of passenger and luggage volume
Midsize	Between 111 to 120 cubic feet of passenger and luggage volume
Large	More than 120 cubic feet of passenger and luggage volume
Two Seater	Automobiles designed primarily to seat only two adults

Note: Station wagons are included with the size class for the sedan of the same class name

In contrast to passenger vehicles, a truck is considered to be an automotive vehicle suitable for hauling.[26] In the United States this generally refers to vehicles with an open load bed such as a pickup and commercial vehicles larger than a normal passenger automobile. Truck sizes are classified according to gross vehicle weight by the U.S. Bureau of Census. These are summarized in Table 2-2, Classification of Truck Sizes.[27]

Table 2-2: Classification of Truck Sizes[28]

Class	Description
Light	Less than 10,000 pounds gross vehicle weight
Medium	Between 10,001 to 20,000 pounds gross vehicle weight
Light Heavy	Between 20,001 to 26,000 pounds gross vehicle weight
Heavy Heavy	26,001 pounds gross vehicle weight or more

This study is specifically focused on passenger vehicles that are primarily powered by electricity. In terms of basics, the three fundamental components comprising the propulsion system of an electric-powered vehicle are the electric motor, the power source such as a battery, and the controller between these two components. Stated differently, the battery or other power source provides the energy, the controller regulates the flow of energy to the motor, and the electric motor drives the wheels. This concept is illustrated in Figure 2-4, Fundamental Components Powering an Electric Vehicle.

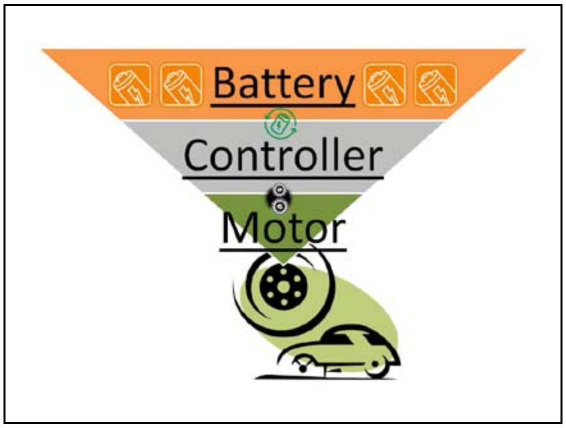


Figure 2-4: Fundamental Components Powering an Electric Vehicle

The storage of energy used to power the electric motor is most commonly through various types of electrochemical battery technology, although other less common approaches are also available using electromechanical storage devices such as a flywheel or a hydraulic accumulator.[29] For electric vehicles they are generally not the method of choice for mass production designs, since they normally are a more expensive approach than batteries and require considerably more equipment.

In its simplest form, a flywheel is a spinning wheel (often under tension), while a hydraulic accumulator stores and releases a fluid under pressure. The gyroscopic effect of a flywheel requires additional design considerations, such as using two contra-rotating flywheels to overcome this problem. Both of these battery-alternative concepts are effective at absorbing and supplying energy and have turnaround energy efficiency as high as 98 percent as compared to batteries at 75 to 80 percent. However, the additional equipment required with a flywheel or a hydraulic accumulator is cost and maintenance intensive, and introduces additional hazards (e.g., fast moving mechanical components, high pressure fluids) for crash victims and emergency responders. It would be unusual for an emergency responder to encounter a vehicle using these technologies for its primary energy storage.

The use of electrochemical batteries for an EV (and NEV) is the most commonly used approach, and the type of technology used is important for emergency responders. Different technologies and configurations are under continual development and each can present their own unique hazards. The most common battery designs today include lead acid, nickel metal hydride (NiMH), and lithium-ion, and the general advantages and disadvantages of each are illustrated in Table 2-3, Common Types of Energy Storage Batteries Used in Vehicles.[30] Figure 2-5 illustrates a typical nickel metal hydride battery module used in an EV.

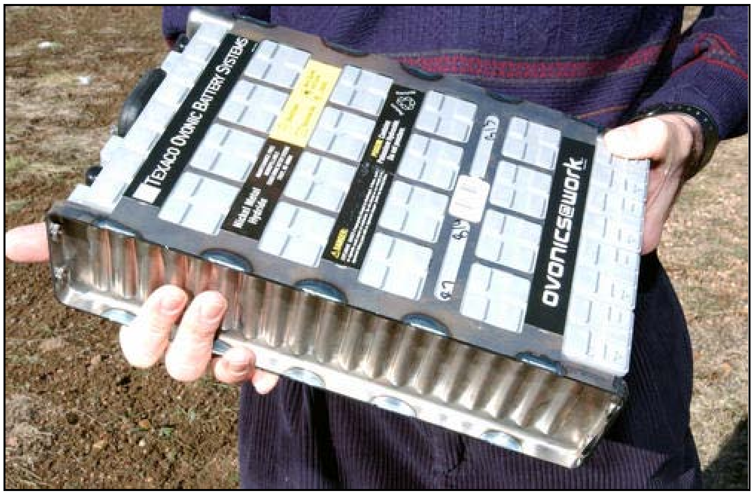


Figure 2-5: NiMH Liquid Cooled EV Battery Module
(Photo courtesy of NREL Photographic Information Exchange)

Each of these three basic electrochemical battery groups contains sub-level variations with certain distinctive enhanced characteristics. For example, the valve-regulated lead acid (VRLA) battery is a type of lead acid battery that provides higher power output but with a shorter life cycle than other designs. Another example are the multiple sub-types of lithium-ion batteries based on the chemical formulations for the electrodes, which include cobalt dioxide, nickel-cobalt-manganese, nickel-cobalt-aluminum, manganese oxide spinel, and iron phosphate.[31] Each of these types of battery storage designs can present unique safety issues for emergency responders during vehicle extrication or fire situation.

Table 2-3: Common Types of Energy Storage Batteries Used in Vehicles[32]

Battery Type	Advantages	Disadvantages
Lead Acid	Low Initial Cost	Short Life Cycle Low Energy Density
Nickel Metal Hydride (Ni-MH)	Moderate to High Energy Density Inherently Safer Materials Steady Battery Output	High Initial Cost High Self-Discharge Rate Poor Low Temperature Operation High Cooling Requirements
Lithium-Ion	High Energy Density Low Self Discharge Rate Good Low Temperature Operation	High initial Cost Lack of Durable Operating Characteristics

Each of these three basic battery technology designs has advantages and disadvantages in terms of initial cost, ongoing maintenance, recharge time, discharge rate, impact by temperature, and other performance characteristics. Some of these qualities balance or cancel each other, such as short life cycle requiring more frequent replacement, thus negating low initial cost. Current research efforts are exploring new battery designs, which may result in new hazard characteristics of interest to emergency responders. Another technology that is being developed is the use of supercapacitator-based approaches that can provide a temporary electrical impulse to assist the propulsion system during high power consumption, such as when the vehicle is accelerating or climbing a hill. Figure 2-6 provides an example of a typical lithium ion EV battery module.

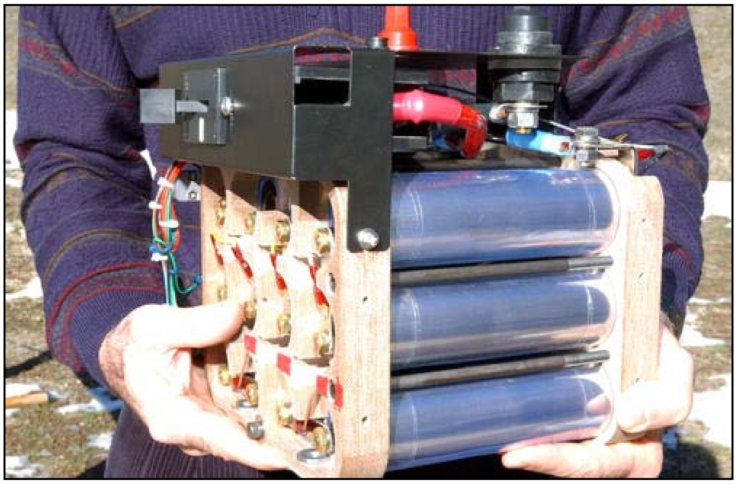


Figure 2-6: Lithium Ion Air Cooled EV Battery Module
(Photo courtesy of NREL Photographic Information Exchange)

Battery systems used in vehicles have certain basic characteristics similar to stationary battery systems installed in structures. These stationary systems often have well-established fire protection design and extinguishing requirements, and in some cases these requirements can be indirectly extrapolated to vehicle battery systems. Examples of such requirements focused on lead acid batteries are contained in Chapter 52 of NFPA 1, *Fire Code*, and Section 608 of the *International Fire Code*.[33,34]

Each type of today's common battery systems (i.e., lead acid, Ni-MH, and lithium ion) has recommended methods for handling by emergency first responders, depending if the incident is a fire, a collision that compromises the casing, or other emergency event (e.g., submersion). Manufacturer's literature often provides specific details of how to handle their particular batteries; however, this information is usually inconsistent in format between manufacturers, and is often not readily accessible for emergency first responders. Standardized guidance for handling vehicle battery–related emergencies and expressly tailored for emergency responders is lacking in the literature. However, this information does exist for non-vehicle-related applications, such as for example, Chapter 52 on Stationary Storage Battery Systems in NFPA 1, *Fire Code*.[35]

Energy storage technology is the focus of continual and noteworthy developments, and the basic approaches used today will likely change. At this time a new technical committee is being established through the Society of Automotive Engineers to address new evolving battery technologies used in vehicles.[36] Advances in battery technology could be a point of major technological advancement for electric vehicles.

Of the various types of batteries used in the current EV and HEV production vehicles, the technology of choice is currently nickel metal hydride (Ni-MH). This choice is illustrated in Table 2-4, Battery Size and Type Used in 2010 Production HEVs.[37]

Table 2-4: Battery Size and Type Used in 2010 U.S. Production Hybrid Electric Vehicles[38]

Manufacturer/Model/ Engine-Transmission Designation	Vehicle Type	Battery Size	Battery Type
Honda Civic Hybrid 4 cyl	Compact Car	158V	Ni-MH
Honda Insight 4 cyl, Auto(AV-S7)	Compact Car	101V	Ni-MH
Honda Insight 4 cyl, Auto(VGR)	Compact Car	101V	Ni-MH
Lexus GS 450h 6 cyl	Compact Car	288V	Ni-MH
Lexus HS 250h 4 cyl	Compact Car	245V	Ni-MH
Chevrolet Malibu Hybrid 4 cyl	MidSize Car	36V	Ni-MH
Ford Fusion Hybrid FWD 4 cyl	MidSize Car	275V	Ni-MH
Mercury Milan Hybrid FWD 4 cyl	MidSize Car	275V	Ni-MH
Nissan Altima Hybrid 4 cyl	MidSize Car	245V	Ni-MH
Toyota Camry Hybrid 4 cyl	MidSize Car	245V	Ni-MH
Toyota Prius 4 cyl (2001 – 2003)	MidSize Car	274V	Ni-MH
Toyota Prius 4 cyl (2004 – 2010)	MidSize Car	202V	Ni-MH
Mercedes-Benz S400 Hybrid 6 cyl	Large Car	126V	Li-Ion
Cadillac Escalade Hybrid 2WD 8 cyl	Sport Utility Vehicle 2WD	300V	Ni-MH
Chevrolet Tahoe Hybrid 2WD 8 cyl	Sport Utility Vehicle 2WD	300V	Ni-MH
Ford Escape Hybrid FWD 4 cyl	Sport Utility Vehicle 2WD	330V	Ni-MH
GMC Yukon 1500 Hybrid 2WD 8 cyl	Sport Utility Vehicle 2WD	300V	Ni-MH
Lexus RX 450h 6 cyl	Sport Utility Vehicle 2WD	300V	Ni-MH
Mazda Tribute Hybrid 2WD 4 cyl	Sport Utility Vehicle 2WD	330V	Ni-MH
Mercury Mariner Hybrid FWD 4 cyl	Sport Utility Vehicle 2WD	330V	Ni-MH
Saturn Vue Hybrid 4 cyl	Sport Utility Vehicle 2WD	36V	Ni-MH
BMW Active Hybrid X6 8 cyl	Sport Utility Vehicle 4WD	312V	Ni-MH
Chevrolet Tahoe Hybrid 4WD 8 cyl	Sport Utility Vehicle 4WD	300V	Ni-MH
Ford Escape Hybrid 4WD 4 cyl	Sport Utility Vehicle 4WD	330V	Ni-MH
GMC Yukon 1500 Hybrid 4WD 8 cyl	Sport Utility Vehicle 4WD	300V	Ni-MH
Lexus RX 450h AWD 6 cyl	Sport Utility Vehicle 4WD	300V	Ni-MH
Mazda Tribute Hybrid 4WD 4 cyl	Sport Utility Vehicle 4WD	330V	Ni-MH
Mercury Mariner Hybrid 4WD 4 cyl	Sport Utility Vehicle 4WD	330V	Ni-MH
Toyota Highlander Hybrid 4WD 6 cyl	Sport Utility Vehicle 4WD	300V	Ni-MH
Chevrolet Silverado 15 Hybrid 2WD 8 cyl	Standard Pickup Truck 2WD	300V	Ni-MH
GMC Sierra 15 Hybrid 2WD 8 cyl	Standard Pickup Truck 2WD	300V	Ni-MH
Chevrolet Silverado 15 Hybrid 4WD 8 cyl	Standard Pickup Truck 4WD	300V	Ni-MH
GMC Sierra 15 Hybrid 4WD 8 cyl	Standard Pickup Truck 4WD	300V	Ni-MH

Notes:

1. cyl = cylinders; VGR = Variable Gear Ratio; Auto = Automatic Transmission
2. 2WD = Two Wheel Drive; 4WD = Four Wheel Drive
3. FWD = Front Wheel Drive; AWD = All Wheel Drive

One example of a new alternative energy storage approach is a recent announcement of a battery-ultracapacitor hybrid involving barium-titanate powders, which claims to outperform the best electrochemical batteries in terms of energy density, inherent safety characteristics, and charge time. It is also claimed to have a more reasonable cost than other leading high performance electrochemical batteries. Specifically it will provide 10 times the energy of lead-acid batteries on a per weight basis, be approximately half the cost, and do so without toxic materials or chemicals.[39]

Overview of Hybrid Electric Vehicles

This section specifically addresses HEVs because there are so many variations of these vehicles and such a wide use of the term *hybrid*. A *hybrid vehicle* is generally understood to be a vehicle with more than one power train.[40]

Specifically, a hybrid electric vehicle (HEV) is a vehicle that combines a conventional propulsion system with a rechargeable energy storage system to achieve enhanced fuel efficiency relative to a vehicle powered by an internal combustion engine (ICE).[41] Just as with the term *electric vehicle*, *hybrid electric vehicle* has multiple definitions in the common literature. The following are several examples:

> Hybrid Electric Vehicle (HEV): A vehicle in which at least one of the energy sources, stores, or converters can deliver electric energy.[42]
>
> Hybrid Electric Vehicle (HEV): A hybrid road vehicle in which the propulsion energy during specified operational missions is available from two or more kinds or types of energy stores, sources, or converters, of which at least one store or converter must be on board.[43]
>
> Hybrid Electric Vehicle (HEV): Any vehicle that has more than one power source.[44]

An HEV most frequently refers to a vehicle that combines electric drive with an ICE or other heat engine using fossil-based fuel. Since the HEV can conceptually include a seemingly endless combination of fuel and energy sources, this study is focused on HEVs that utilize electric battery powered propulsion in conjunction with ICE powered propulsion. Other variations of HEVs, such as hybrid vehicles that utilize electromechanical energy storage rather than batteries, or heat engines and/or fuel cells that utilize fuel other than gasoline, are beyond the scope of this report.

The HEV is a technological bridge that addresses the environmental concerns for more sustainable and fuel efficient vehicles, and the limited practicality of today's purely electric vehicles. The overall purpose of blending the available multiple technologies is to: (1) supply the necessary vehicle performance power demands; (2) support desired driving range with on-board energy sources; (3) provide optimum energy efficiency; and (4) minimize environmental impact.[45] For HEVs, a common feature is that they will recharge their battery by capturing kinetic energy generated through regenerative braking and through an electric motor/generator that is regulated through a controller.

A technological extension of the HEV that has been recognized as its own class of vehicle is the *plug-in hybrid electric vehicle* (PHEV). These are simply HEVs that include a plug-in option to recharge the vehicles batteries, thus addressing the limited range problem that is a frequent handicap to an HEV. This allows the average commuter to drive all electric while close to home, while on longer range excursions the downsized gasoline engine operates like a regular HEV. Figure 2-7 illustrates the primary propulsion components of a typical PHEV.

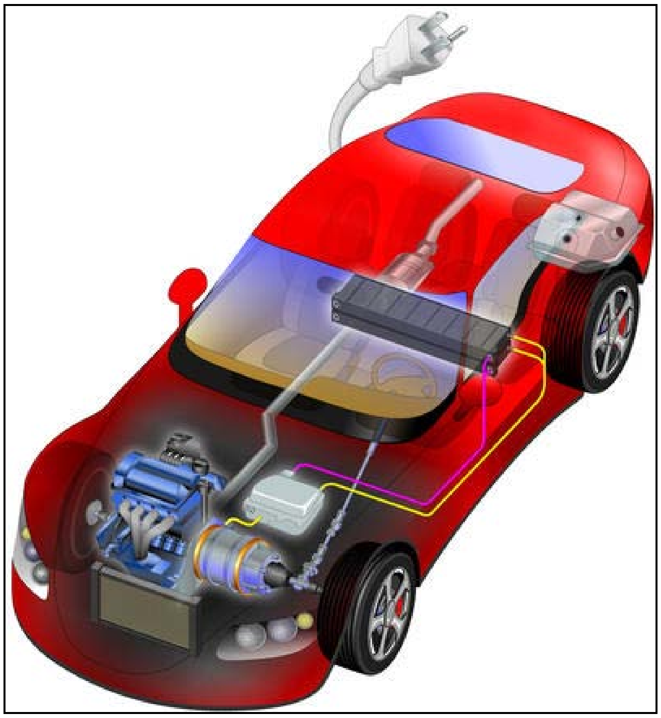


Figure 2-7: PHEV Diagram of Primary Components
(Photo courtesy of NREL Photographic Information Exchange)

The PHEV is a relatively simple variation of the HEV for the vehicle itself, but collectively it introduces new implications to the transportation and energy infrastructure. The electric vehicle connected to its charging station can become a power source to the electric grid during a power outage, and absent electrical system design features that would limit back-feeding, this introduces additional concerns for emergency responders who are attempting to isolate electric power during an emergency. The ability to control the back-feeding of electrical energy from the vehicle back to the charging station (and building electrical system) is a technical issue actively being addressed in the code requirements for charging station installations.

Conceptually an HEV and PHEV is not a complicated design. The fuel efficiency of a conventional gasoline powered vehicle can be increased by as much as 50% through the addition of an electric motor, controller, and rechargeable batteries to convert it to an HEV.

The range of power plant combinations and how they interact generates several subcategories of HEVs.

A general understanding of what is a *full hybrid* versus a *mild hybrid* can be found in the literature. A full hybrid is a term often used to describe a vehicle that is propelled at relatively low speeds without consuming gasoline. A mild hybrid describes cars that can move from a standstill only if the ICE is engaged, and uses the electric motor primarily to assist the gas-powered engine when extra power is needed.[46] Both the full hybrid and the mild hybrid require the use of the ICE at higher speeds such as on the highway. These baseline descriptions, however, continue to be subject to updates to address new technology advancements. An example is the new Ford Fusion hybrid, which is considered a full hybrid, and yet is able to travel up to roughly 42 mph on electric power alone, which is arguably considered beyond *relatively low speed*.

Thus the degree to which a hybrid design is either "full" or "mild" is not precisely defined, but rather exists as part of a wide spectrum. Every small design detail of the HEV propulsion system is typically used to improve the performance and efficiency of the vehicle and to minimize fuel consumption. This concept is illustrated in Figure 2-8, Spectrum of the Types of Hybrid Vehicles. Mild hybrids include the following subcategories:[47]

- *Start/Stop Hybrid* shuts off an idling ICE and restarts it instantly on demand;
- *Integrated Starter Alternator with Damping (ISAD) Hybrid* uses the electric motor to help move the vehicle in addition to providing start/stop capability; and
- *Integrated Motor Assist (IMA) Hybrid* also uses the electric motor to help move the vehicle in addition to providing start/stop capability, but has a larger electric motor and more electricity to propel the vehicle.

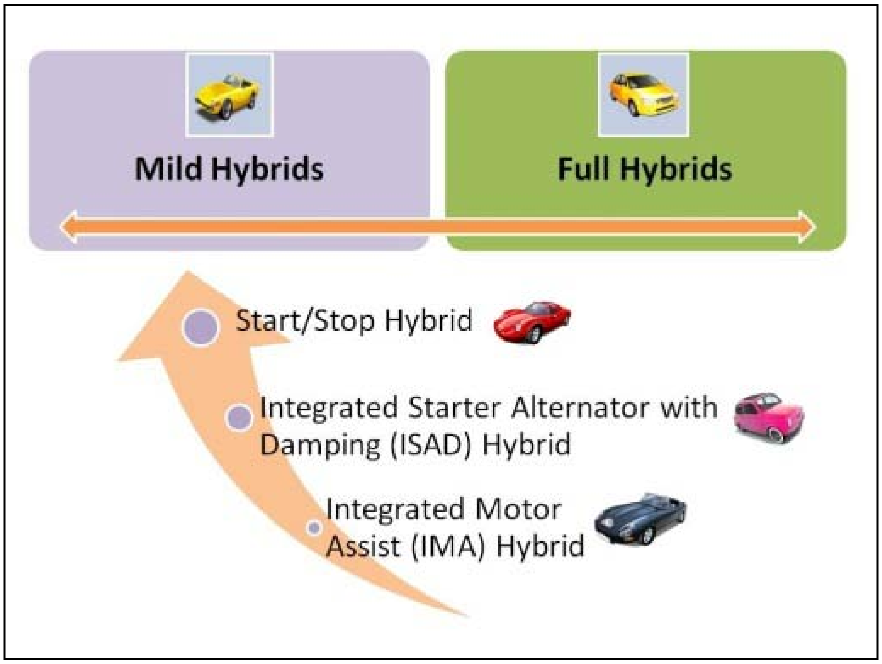


Figure 2-8: Spectrum of the Types of Hybrid Vehicles

The simplicity of a conventional gasoline-powered automobile is illustrated in Figure 2-9, Internal Combustion Engine Power Train. Here, the ICE is engaged through a transmission to the wheels that directly power the vehicle. Figure 2-10, Plug-in Electric Vehicle Power Train, illustrates an EV with a charging plug, and is similar to the ICE-propelled vehicle in its simplicity. While this is relatively straightforward for an EV, the possible variations with an HEV allow for a multitude of configurations.

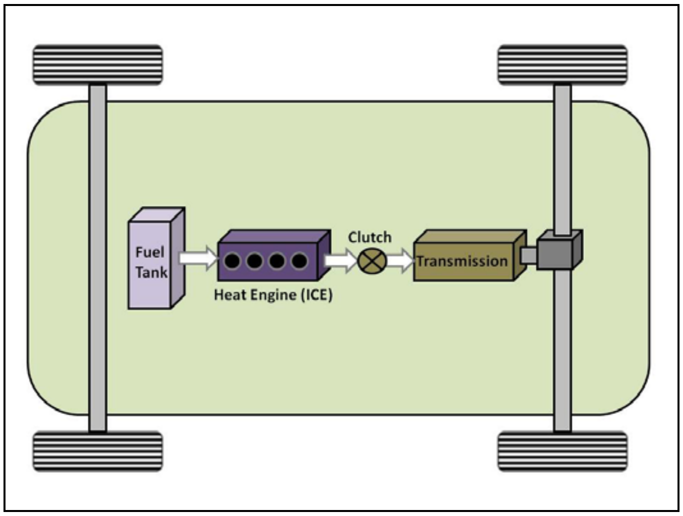


Figure 2-9: Internal Combustion Engine (ICE) Power Train

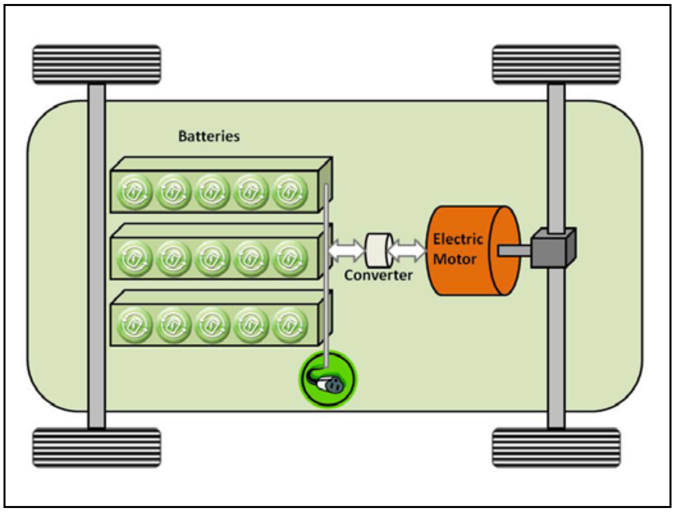


Figure 2-10: Plug-in Electric Vehicle Power Train

There are three basic configurations of HEV propulsion design: series, parallel, and series parallel.[48] In a series hybrid, mechanical output of the heat engine is used to generate electrical power through a generator that charges the battery system or powers the electric motor, but does not directly transmit mechanical power to propel the wheels. This is illustrated in Figure 2-11, Series Hybrid Electric Vehicle Power Train.

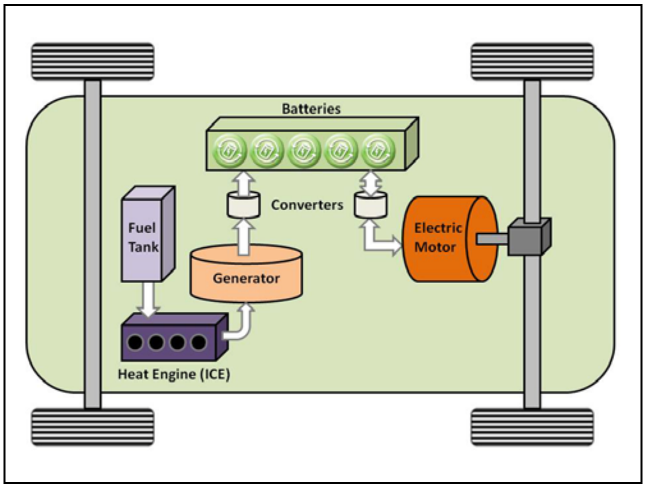


Figure 2-11: Series Hybrid Electric Vehicle Power-Train

In a parallel hybrid configuration, the mechanical output of the heat engine is transmitted to the wheels through a three-way gear box with the assistance of a continuously variable transmission. The electric motor is likewise linked directly into this three-way gear box, and is continuously used in parallel with the ICE. The electric batteries supply power to the electric motor, while independently the gasoline fuel tank supplies fuel to the ICE. The parallel hybrid configuration is illustrated in Figure 2-12, Parallel Hybrid Electric Vehicle Power Train.

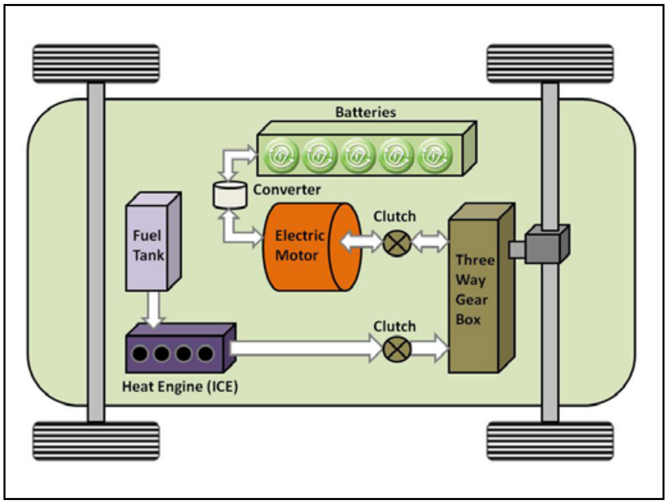


Figure 2-12: Parallel Hybrid Electric Vehicle Power Train

The series–parallel hybrid configuration combines the best of both design concepts based on both a series and parallel configuration type design.[49] Here, the ICE not only directly propels the vehicle through the three-way gear box but also powers an electrical generator that recharges the batteries. Meanwhile, the batteries power the electrical motor that also directly propels the vehicle through the three-way gear box. Computer control mechanisms engage each propulsion system when it is needed. Figure 2-13, Series–Parallel Hybrid Electric Vehicle Power Train, illustrates the basic components found in a series–parallel hybrid configuration. Today's HEVs are most commonly parallel hybrids or series–parallel hybrids.

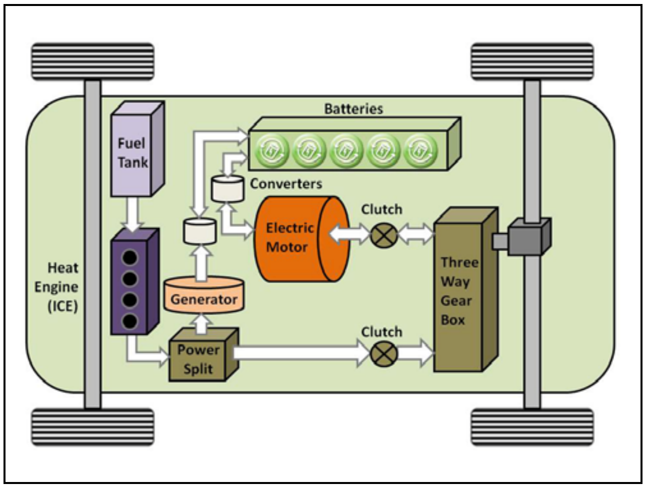


Figure 2-13: Series-Parallel Hybrid Electric Vehicle Power Train

Marketplace Trends

The auto industry has traditionally been impacted by the volatility of overall economic conditions, and the trends that apply to the overall automobile market also apply to EV and HEV sales as well. Yet these cars are generally more expensive, and this can be a significant handicap to increasing their popularity among consumers.[50]

Nearly every automaker has or is working on some form of alternative-fuel car, and many have some variation of an EV or HEV. The last decade has seen an increasing trend in the number of EV and HEV production vehicles available from mainstream automakers. The number of hybrid electric vehicles available in the marketplace since 2000 and projected through 2010 is illustrated in Figure 2-14, Electric Hybrid Production Vehicles Available by Year.[51, 52]

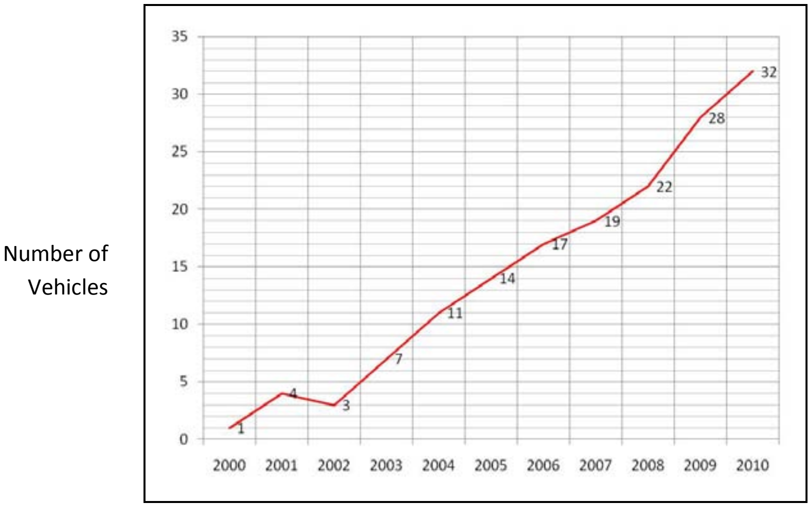


Figure 2-14: Electric Hybrid Production Vehicles Available by Year[54]

The number of HEVs available from the mainstream automakers is on an upward trend, and similarly their share of the market likewise is growing amidst overall sluggish auto sales. However, their total numbers are not overwhelming and the projected rate of growth is not dramatic. Generally, the last two decades have seen an increase in the number of vehicles that use alternative fuels (i.e., fuels other than gasoline or diesel), and this trend is expected to continue based on the ongoing need to reduce dependence on foreign oil and utilize renewable energy sources that do not adversely affect the environment. However up-front cost still remains an important barrier for widespread proliferation of EVs and HEVs.[53]

The auto industry is facing a new era of significant change, based on challenges in consumer demands, technology development, globalization, integrated operations, and collaboration strategies. Factors that are expected to have substantive impact include more sophisticated consumers, enhanced intelligent vehicles, dynamic business operating methods, entrepreneurial global marketplace, and an interdependent ecosystem.[55]

Table 2-5: HEV Sales Estimates, 1999 – 2007[57]

Model	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Honda Insight	17	3,788	4,726	2,216	1,200	583	666	722	-	13,918
Toyota Prius	-	5,562	15,556	20,119	24,600	53,991	107,897	106,971	181,221	515,917
Honda Civic	-	-	-	13,700	21,800	25,571	18,797	31,251	32,575	143,694
Ford Escape	-	-	-	-	-	2,993	15,800	20,149	21,386	60,328
Honda Accord	-	-	-	-	-	1,061	16,826	5,598	3,405	26,890
Lexus RX 400h	-	-	-	-	-	-	20,674	20,161	17,291	58,126
Toyota Highlander	-	-	-	-	-	-	17,989	31,485	22,052	71,526
Mercury Mariner	-	-	-	-	-	-	998	3,174	3,722	7,894
Lexus GS 450h	-	-	-	-	-	-	-	1,784	1,645	3,429
Toyota Camry	-	-	-	-	-	-	-	31,341	54,477	85,818
Nissan Altima	-	-	-	-	-	-	-	-	8,388	8,388
Saturn Vue	-	-	-	-	-	-	-	-	4,403	4,403
Lexus LS600hL	-	-	-	-	-	-	-	-	937	937
Saturn Aura	-	-	-	-	-	-	-	-	772	772
Total	17	9,350	20,282	36,035	47,600	84,199	199,647	252,636	352,274	1,002,040

A key indicator of marketplace activity is the annual sales of HEVs. This is illustrated in Table 2-5, which provides an annual estimate of HEV sales for 14 popular models from 1999 through 2007.[56] In this eight-year period the sales growth in units sold has been steady, with the Toyota Prius leading all other models and providing more than half of the approximate one million HEV sales (by number of vehicles) in this time frame. Figure 2-15 shows a 2004 model of the Toyota Prius.

Figure 2-15: 2004 Toyota Prius
(Photo courtesy of NREL Photographic Information Exchange)

A different measurement of vehicle popularity is the number of vehicles in use during any given year. Data for *vehicles in use* is based on accumulated acquisitions, less retirements, as of the end of each calendar year, not including concept and demonstration vehicles that are not ready for delivery to end users. The estimated number of electric vehicles (EVs and HEVs, but excluding gasoline-powered hybrids) in use in the United States for the time frame between 1995 to 2007 is captured in Table 2-6, Vehicles in Use, 1995–2007.[58] During this time period the average percent change of all alternative-fueled vehicles has been a healthy 9.1 percent per year.

But this is eclipsed by the increase in the number of electric vehicles, which has seen a dramatic 30.6 percent per year rise during this same span of time, despite flattening off the last 4 years due to relatively low gasoline prices. This contrasts with the modest overall growth in the number of vehicles at an average of 2.3 percent per year, indicating the sharp increase in interest in this particular technology. The recent federal funding effort by the Obama Administration to stimulate electric car technology development is expected to further enhance this growth.[59]

Overall, however, Table 2-6 also indicates that alternative-fueled vehicles account for less than one percent of the overall number of vehicles on the road, and electric-powered vehicles even less. Because overall numbers are still relatively small, emergency incidents involving first responders with these alternative-fueled vehicles will likely be infrequent, though not necessarily unusual on occasion.

Table 2-6: Vehicles in Use, 1995–2007[60]

YEAR	NUMBER OF ELECTRIC VEHICLES[1]	PERCENT CHANGE (%)	TOTAL ALTERNATIVE FUEL VEHICLES[2]	PERCENT CHANGE (%)	TOTAL NUMBER OF VEHICLES[3]	PERCENT CHANGE (%)
1995	2,860	---	246,855	---	200,845,000	---
1996	3,280	14.7	265,006	7.3	205,669,000	2.4
1997	4,453	35.8	280,205	5.7	207,056,000	0.7
1998	5,243	17.7	295,030	5.3	210,901,000	1.9
1999	6,964	32.8	322,302	9.2	215,580,000	2.2
2000	11,830	69.9	394,664	22.4	220,729,000	2.4
2001	17,847	50.7	425,457	7.8	229,678,000	4.0
2002	33,047	85.1	471,098	10.7	228,860,000	-0.4
2003	47,485	43.7	533,999	13.3	230,614,000	7.7
2004	49,536	4.3	565,492	5.9	236,447,000	2.5
2005	51,398	3.8	592,122	4.7	240,387,000	1.7
2006	53,526	4.1	634,562	7.2	243,344,000	1.2
2007	55,730	4.1	695,766	9.6	246,431,000	1.3
Avg %:		**30.6**		**9.1**		**2.3**

Note 1: Includes EVs and HEVs, but excluding gasoline powered HEVs.[61]

Note 2: Based on vehicles that use alternative fuels, including Electricity, Hydrogen, LPG (liquefied petroleum gas), CNG (compressed natural gas), LNG (liquefied natural gas), M100 (100% methanol), E85 (85% ethanol & 15% gasoline), and E95 (95% ethanol & 5% gasoline).[62]

Note 3: Represents total U.S. cars and trucks in use, based on data collected by FHWA.[63]

The use of LP-Gas is currently the most widely used alternative fuel for motor vehicles, although the use of both CNG and LNG is increasing. The types of alternative fuels used for motor vehicles are based on classifications set by the U.S. Environmental Protection Agency, through the Clean Air Act Amendment of 1990 and Energy Policy Act of 1992. Electricity is only one of ten recognized alternative fuels, and to better understand the relationship between electricity and these other fuels, they are illustrated in Figure 2-16, Types of Alternative Fuels Used in Motor Vehicles.[64, 65]

Certain regions of the United States have also seen higher usage based on state-based policies and programs, such as California. Not surprisingly the rate of emergency incidents involving these types of vehicles will vary from state to state. One indication of the proliferation of this technology in certain parts of the United States is indicated in Table 2-7, Number of Electric Vehicle Refuel Sites by State. This indicates which states have been actively promoting alternative vehicle technologies. Clearly, the State of California leads all other states with almost 85 percent of the electric refueling sites in the United States.

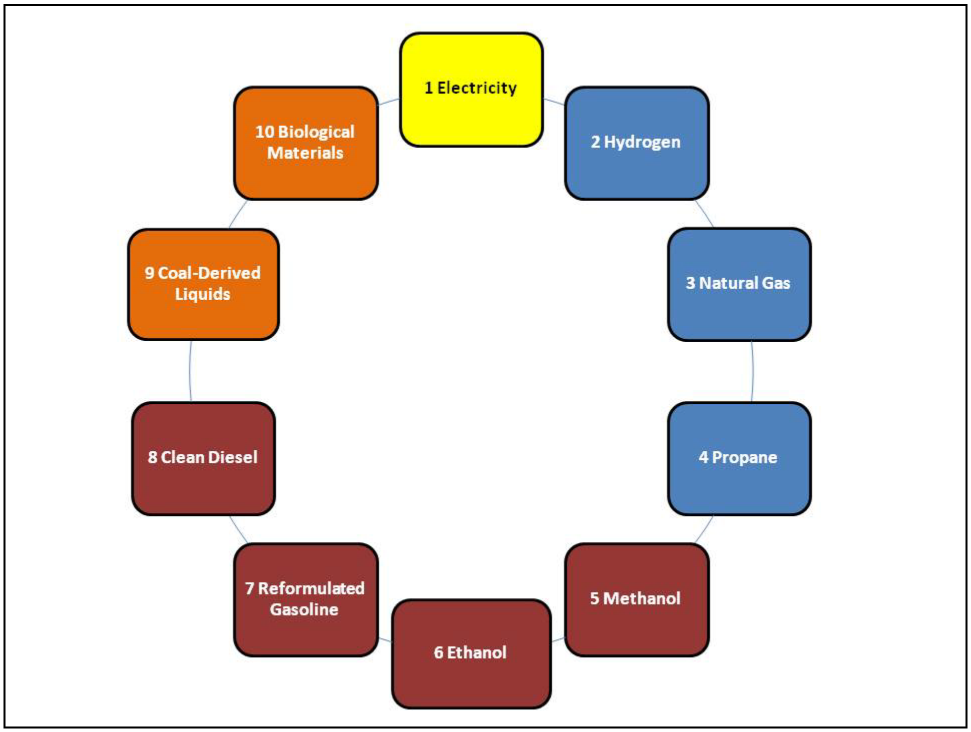


Figure 2-16: Types of Alternative Fuels Used in Motor Vehicles[66, 67]

Table 2-7: Number of Electric Vehicle Refuel Sites by State, 2009[68]

STATE	No.	%	STATE	No.	%	STATE	No.	%
Arizona	15	3.1	**Illinois**	5	1.0	**Rhode Island**	2	0.4
California	404	84.9	**Massachusetts**	12	2.5	**Texas**	1	0.2
Connecticut	3	0.6	**New Hampshire**	8	1.7	**Vermont**	2	0.4
Florida	3	0.6	**New York**	1	0.2	**Virginia**	1	0.2
Hawaii	3	0.6	**Oregon**	14	2.9	**Washington**	2	0.4

Note: Total for the 15 states with electric vehicle refueling sites is 476. Other states have zero sites.

Summary of Current Vehicles

The spectrum of today's new technology and the varieties of motor vehicles that may be encountered by emergency responders is diverse and can seem daunting. Each year new models are being introduced while existing models are discontinued. Meanwhile the discontinued models remain in operation for years until they disappear through normal attrition.

Table 2-8, Existing Hybrid Electric Vehicles Produced in the U.S. Since 2000, provides a useful summary of the existing HEVs in production in the United States during the last decade. These are the vehicles most likely to be encountered by today's emergency responders.

Table 2-8: Existing Hybrid Electric Vehicles Produced in the U.S. Since 2000[69]

Manufacturer/Model/ Engine-Transmission Designation	Production Year										
BMW Active Hybrid X6 8 cyl	10										
Cadillac Escalade Hybrid 2WD 8 cyl	10	09									
Chevrolet Malibu Hybrid 4 cyl	10	09	08								
Chevrolet Silverado 15 Hybrid 2WD 8 cyl	10	09			06	05	04				
Chevrolet Silverado 15 Hybrid 4WD 8 cyl	10	09			06	05	04				
Chevrolet Silverado Classic 15 Hybrid 2WD 8 cyl				07							
Chevrolet Silverado Classic 15 Hybrid 4WD 8 cyl				07							
Chevrolet Tahoe Hybrid 2WD 8 cyl	10	09	08								
Chevrolet Tahoe Hybrid 4WD 8 cyl	10	09	08								
Chrysler Aspen HEV 8 cyl		09									
Dodge Durango HEV 8 cyl		09									
Ford Escape Hybrid 2WD 4 cyl						05					
Ford Escape Hybrid 4WD 4 cyl	10	09	08	07	06	05					
Ford Escape Hybrid FWD 4 cyl	10	09	08	07	06						
Ford Fusion Hybrid FWD 4 cyl	10										
GMC Sierra 15 Hybrid 2WD 8 cyl	10	09			06	05	04				
GMC Sierra 15 Hybrid 4WD 8 cyl	10	09			06	05	04				
GMC Sierra Classic 15 Hybrid 2WD 8 cyl				07							
GMC Sierra Classic 15 Hybrid 4WD 8 cyl				07							
GMC Yukon 1500 Hybrid 2WD 8 cyl	10	09	08								
GMC Yukon 1500 Hybrid 4WD 8 cyl	10	09	08								
Honda Accord Hybrid 6 cyl				07	06	05					
Honda Civic Hybrid 4 cyl	10	09	08	07	06						
Honda Civic Hybrid 4 cyl, Auto(VGR)							04	03			
Honda Civic Hybrid 4 cyl, Auto(VGR) HEV						05					
Honda Civic Hybrid 4 cyl, Auto(VGR) HEV LB						05					
Honda Civic Hybrid 4 cyl, Auto(VGR), LB							04	03			
Honda Civic Hybrid 4 cyl, Manual 5-spd							04	03			
Honda Civic Hybrid 4 cyl, Manual 5-spd HEV						05					
Honda Civic Hybrid 4 cyl, Manual 5-spd, LB						05	04	03			
Honda Insight 3 cyl, Auto(VGR) VTEC					06	05	04	03	02	01	
Honda Insight 3 cyl, Manual 5-spd VTEC						05	04	03	02	01	00
Honda Insight 4 cyl, Auto(AV-S7)	10										
Honda Insight 4 cyl, Auto(VGR)	10										
Lexus GS 450h 6 cyl	10	09	08	07							
Lexus HS 250h 4 cyl	10										
Lexus LS 600h L 8 cyl		09	08								
Lexus RX 400h 2WD 6 cyl			08	07	06						
Lexus RX 400h 4WD 6 cyl			08	07	06						
Lexus RX 450h 6 cyl	10										
Lexus RX 450h AWD 6 cyl	10										
Mazda Tribute Hybrid 2WD 4 cyl	10	09	08								
Mazda Tribute Hybrid 4WD 4 cyl	10	09	08		06						
Mercedes-Benz S400 Hybrid 6 cyl	10										
Mercury Mariner Hybrid 4WD 4 cyl	10	09	08	07	06						
Mercury Mariner Hybrid FWD 4 cyl	10	09	08								
Mercury Milan Hybrid FWD 4 cyl	10										

Manufacturer/Model/ Engine-Transmission Designation	Production Year										
Nissan Altima Hybrid 4 cyl	10	09	08	07							
Saturn Aura Hybrid 4 cyl		09	08	07							
Saturn Vue Hybrid 4 cyl	10	09	08	07							
Saturn Vue Hybrid 6 cyl		09									
Toyota Camry Hybrid 4 cyl	10	09	08	07							
Toyota Highlander Hybrid 2WD 6 cyl				07	06						
Toyota Highlander Hybrid 4WD 6 cyl	10	09	08	07	06						
Toyota Prius 4 cyl	10	09	08	07	06	05	04	03	02	01	

Notes:

4. cyl = cylinders; LB = Lean Burn; HEV = Hybrid Electric Vehicle
5. VGR = Variable Gear Ratio; VTEC = Variable Valve Timing and Lift Electronic Control
6. 2WD = Two Wheel Drive; 4WD = Four Wheel Drive
7. FWD = Front Wheel Drive; AWD = All Wheel Drive
8. Auto = Automatic Transmission; Manual = Manual Transmission

A list of available vehicles included within the scope of this project is included in Table C-1 of Annex C, Overall Summary of Electric and Hybrid Electric Vehicles. This addresses vehicles that are sedans (two- or four-door passenger vehicle with at least four seats), coupes (two-seat passenger vehicle), SUVs (sports utility vehicles), pickups, and vans, but does not include trucks, buses, recreational, construction, farm and other similar vehicles. It also addresses EVs (electric vehicles), HEVs (hybrid electric vehicles), PHEVs (plug-in hybrid electric vehicles), and NEVs (neighborhood electric vehicles). With regard to model years, it includes vehicles that are no longer produced (since 1990), current vehicles in production, and concept prototypes. A vehicle that has moved beyond the prototype stage and is considered a production vehicle is a vehicle that is readily available in the marketplace to the general consumer.

In 2007, there were 7,618,000 new retail passenger car sales in the United States, with 5,253,000 produced domestically and 2,365,000 imported from outside North America.[70] For convenience a series of additional tables are provided that are a subset of Annex C, Overall Summary of Electric and Hybrid Electric Vehicles. These include the following:

- Table 2-9, Summary of Electric Vehicles (EVs);
- Table 2-10: Summary of Hybrid Electric Vehicles (HEVs);
- Table 2-11: Summary of Plug-in Hybrid Electric Vehicles (PHEVs);
- Table 2-12: Summary of Neighborhood Electric Vehicles (NEVs);
- Table 2-13: Summary of Recent Discontinued Vehicles (EVs, HEVs, PHEVs, NEVs); and
- Table 2-14: Summary of Concept or Prototype Vehicles (EVs, HEVs, PHEVs, NEVs).

Table 2-9: Summary of Electric Vehicles (EVs) [71,72,73]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
AC Propulsion	**eBox**	Sedan	EV	2009	www.acpropulsion.com
BMW	**City**	Coupe	EV	2012	www.bmwusa.com
BYD	**E6**	Sedan	EV	Concept	www.byd.com
Chevrolet	**S-10 Electric**	Pickup	EV	D/NLP	www.chevrolet.com/hybrid
Chrysler	**Epic Electric Minivan**	Van	EV	D/NLP	www.chrysler.com
Coda Auto	**Hafei Saibao 3 EV**	Sedan	EV	2010	www.codaautomotive.com
Daimler	**Smart For Two (ED)**	Coupe	EV	2010	www.smartusa.com
Dodge	**Circuit**	Coupe	EV	2011	www.dodge.com
Ford	**Electric Ranger**	Pickup	EV	D/NLP	www.ford.com
	Focus EV	Sedan	EV	2011	www.ford.com
GMC	**EV1**	Sedan	EV	D/NLP	www.gmc.com
Honda	**EV Plus**	Sedan	EV	D/NLP	www.honda.com
Keio	**Eliica**	Coupe	EV	Concept	www.eliica.com/English/
Lightning	**GT**	Coupe	EV	2010	www.lightningcarcompany.com
Mercedes	**BlueZero**	Sedan	EV	Concept	mbusa.com
Miles EV	**ZX 40S**	Sedan	EV	2009	www.milesev.com
Mini Cooper	**Mini E**	Sedan	EV	Concept	www.miniusa.com
Mitsubishi	**iMiEV**	Sedan	EV	Concept	www.mitsubishicars.com
Modec	**Box Van**	Van	EV	2009	www.modeczev.com
Mullen	**L1x-75**	Coupe	EV	Concept	www.mullenmotorco.com
Nissan	**Altra**	Sedan	EV	D/NLP	www.nissanusa.com
	Leaf	Sedan	EV	2010	www.nissanusa.com
Phoenix	**Phoenix SUV**	SUV	EV	D/NLP	www.phoenixmotorcars.com
	Phoenix Pickup	Pickup	EV	D/NLP	www.phoenixmotorcars.com
Pininfarina	**Blue Car**	Sedan	EV	2010	www.pininfarina.com
Porteon	**EV**	Sedan	EV	Concept	www.porteon.net
Renault	**Fluence**	Coupe	EV	2011	www.renault.com
Smith	**Edison Panel Van**	Van	EV	2009	www.smithelectricvehicles.com
Solectria	**Force**	Sedan	EV	D/NLP	www.azuredynamics.com
Subaru	**R1E**	Coupe	EV	Concept	www.subaru.com
Tesla	**Model S**	Coupe	EV	2011	www.teslamotors.com
	Roadster	Coupe	EV	2009	www.teslamotors.com
Think	**Th!nk City**	Coupe	EV	2009	www.think.no
Toyota	**RAV4 EV**	SUV	EV	D/NLP	www.toyota.com/hsd
	FT-EV	Coupe	EV	Concept	www.toyota.com/hsd
Universal	**UEV Spyder**	Coupe	EV	D/NLP	n/a
Velozzi	**Supercar**	Coupe	EV	Concept	www.velozzi.org
Venturi	**Fetish**	Coupe	EV	2009	www.venturifetish.fr
Wrightspeed	**X1**	Coupe	EV	Concept	www.wrightspeed.com

Table 2-10: Summary of Hybrid Electric Vehicles (HEVs) [74,75,76]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
Audi	**Q7 TDI Hybrid**	SUV	HEV	Concept	www.audiusa.com
BMW	**ActiveHybrid 7**	Sedan	HEV	2010	www.bmwusa.com
	X6 Hybrid	SUV	HEV	2010	www.bmwusa.com
Cadillac	**Escalade Hybrid**	SUV	HEV	2009	www.cadillac.com
Chevrolet	**Malibu**	Sedan	HEV	2009	www.chevrolet.com/hybrid
	Silverado Hybrid	Pickup	HEV	2009	www.chevrolet.com/hybrid
	Tahoe Hybrid	SUV	HEV	2009	www.chevrolet.com/hybrid
Chrysler	**Aspen Hybrid**	SUV	HEV	D/NLP	www.chrysler.com/en/2009/aspen/hybrid/
Dodge	**Ram Hybrid**	Pickup	HEV	2010	www.dodge.com
	Durango Hybrid	SUV	HEV	D/NLP	www.dodge.com
	Grand Caravan Hybrid	Van	HEV	Concept	www.dodge.com
Ford	**Reflex**	Coupe	HEV	Concept	www.ford.com
	Fusion Hybrid	Sedan	HEV	2009	www.ford.com
	Escape Hybrid	SUV	HEV	2009	www.ford.com
GMC	**Sierra Hybrid**	Pickup	HEV	2009	www.gmc.com
	Yukon Hybrid	SUV	HEV	2009	www.gmc.com
Honda	**CR-Z Hybrid**	Coupe	HEV	2010	www.honda.com
	Civic Hybrid	Sedan	HEV	2009	www.honda.com
	Insight	Sedan	HEV	2009	www.honda.com
	Fit Hybrid	Sedan	HEV	2010	www.honda.com
	Accord Hybrid	Sedan	HEV	D/NLP	www.honda.com
Hyundai	**Sonata Hybrid**	Sedan	HEV	2010	www.hyundaiusa.com
	Accent Hybrid	Sedan	HEV	2010	www.hyundaiusa.com
Infiniti	**M35 Hybrid**	Sedan	HEV	2011	www.infinitiusa.com
Lexus	**HS 250h**	Sedan	HEV	2009	www.lexus.com
	GS 450h	Sedan	HEV	2009	www.lexus.com
	LS 600h L	Sedan	HEV	2009	www.lexus.com
	RX 450h	SUV	HEV	2009	www.lexus.com
	RX 400h	SUV	HEV	2009	www.lexus.com
Mazda	**Tribute HEV**	SUV	HEV	2009	www.mazdausa.com
Mercedes	**S400 Blue Hybrid**	Sedan	HEV	2009	mbusa.com
	ML 450 Hybrid	SUV	HEV	2009	mbusa.com
Mercury	**Milan Hybrid**	Sedan	HEV	2009	www.mercuryvehicles.com
	Mariner Hybrid	SUV	HEV	2009	www.mercuryvehicles.com
	Meta One	Van	HEV	Concept	www.mercuryvehicles.com
Nissan	**Altima Hybrid**	Sedan	HEV	2009	www.nissanusa.com
Porsche	**Cayenne S Hybrid**	SUV	HEV	2010	www.porsche.com
Saab	**BioPower Hybrid**	Sedan	HEV	Concept	www.saabusa.com
Toyota	**Volta**	Coupe	HEV	Concept	www.toyota.com/hsd
	A-BAT Hybrid Truck	Pickup	HEV	Concept	www.toyota.com/hsd
	Prius	Sedan	HEV	2009	www.toyota.com/hsd
	Camry Hybrid	Sedan	HEV	2009	www.toyota.com/hsd
	Hybrid X	Sedan	HEV	Concept	www.toyota.com/hsd
	Highlander Hybrid	SUV	HEV	2009	www.toyota.com/hsd
	Sienna Hybrid	Van	HEV	Concept	www.toyota.com/hsd
Volkswagen	**Touareg Hybrid**	SUV	HEV	2011	www.vw.com
Volvo	**3CCC**	Coupe	HEV	Concept	www.volvo.com

Table 2-11: Summary of Plug-in Hybrid Electric Vehicles (PHEVs)[77,78,79]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
Cadillac	**Converj**	Sedan	PHEV	Concept	www.cadillac.com
Chevrolet	**Volt**	Sedan	PHEV	2010	www.chevrolet.com/hybrid
Fisker	**Karma**	Luxury	PHEV	2010	karma.fiskerautomotive.com
Ford	**Escape Plug-in Hybrid**	SUV	PHEV	2012	www.ford.com
GMC	**Plug-in Crossover SUV**	SUV	PHEV	2011	www.gmc.com
Toyota	**Prius Plug-in**	Sedan	PHEV	2012	www.toyota.com/hsd
Volvo	**V70 Plug-in Hybrid**	Van	PHEV	2012	www.volvo.com

Table 2-12: Summary of Neighborhood Electric Vehicles (NEVs)[80,81,82]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
AEV	**Kurrent**	Coupe	NEV	2009	www.getkurrent.com
Aptera	**2E**	Coupe	NEV	2009	www.aptera.com
BB Buggies	**Bad Boy Buggy**	Coupe	NEV	2009	www.badboybuggies.com
BG Auto	**BG C100**	Coupe	NEV	2009	www.bgelectriccars.com
Commuter	**Tango T600**	Coupe	NEV	2009	www.commutercars.com
Dynasty	**IT**	Coupe	NEV	2009	www.itiselectric.com
Elbilen	**Buddy**	Coupe	NEV	2009	www.elbilnorge.no
FineMobile	**Twike**	Coupe	NEV	2009	www.twike.us
Flybo	**XFD-6000ZK**	Coupe	NEV	2009	www.flybo.cn
GEM	**GEM Car**	Coupe	NEV	2009	www.gemcar.com
Myers	**NmG**	Coupe	NEV	2009	www.myersmoters.com
Obvio	**828e**	Coupe	NEV	2009	www.obvio.ind.br
Reva	**NXR / NXG**	Coupe	NEV	2009	www.revaglobal.com
Spark Electric	**Comet**	Coupe	NEV	D/NLP	n/a
Venture	**Pursu**	Coupe	NEV	2009	www.flytheroad.com
	VentureOne e50	Coupe	NEV	Concept	xprizecars.com/2008/06/venture-vehicles-ventureone.php
Zap	**Xebra**	Coupe	NEV	2009	www.zapworld.com
Zenn Motors	**CityZenn**	Coupe	NEV	2009	www.zenncars.com

Table 2-13: Summary of Recent Discontinued Vehicles (EVs, HEVs, PHEVs, NEVs)[83,84,85]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
Chevrolet	**S-10 Electric**	Pickup	EV	D/NLP	www.chevrolet.com/hybrid
Chrysler	**Aspen Hybrid**	SUV	HEV	D/NLP	www.chrysler.com/en/2009/aspen/hybrid/
	Epic Electric Minivan	Van	EV	D/NLP	www.chrysler.com
Dodge	**Durango Hybrid**	SUV	HEV	D/NLP	www.dodge.com
Ford	**Electric Ranger**	Pickup	EV	D/NLP	www.ford.com
GMC	**EV1**	Sedan	EV	D/NLP	www.gmc.com
Honda	**EV Plus**	Sedan	EV	D/NLP	www.honda.com
	Accord Hybrid	Sedan	HEV	D/NLP	www.honda.com
Nissan	**Altra**	Sedan	EV	D/NLP	www.nissanusa.com
Phoenix	**Phoenix SUV**	SUV	EV	D/NLP	www.phoenixmotorcars.com
	Phoenix Pickup	Pickup	EV	D/NLP	www.phoenixmotorcars.com
Saturn	**Aura**	Sedan	HEV	D/NLP	www.saturn.com
	Vue Hybrid	SUV	HEV	D/NLP	www.saturn.com
	Vue Green Line 2-Mode	SUV	HEV	D/NLP	www.saturn.com
Solectria	**Force**	Sedan	EV	D/NLP	www.azuredynamics.com
Spark Electric	**Comet**	Coupe	NEV	D/NLP	n/a
Toyota	**RAV4 EV**	SUV	EV	D/NLP	www.toyota.com/hsd
Universal	**UEV Spyder**	Coupe	EV	D/NLP	n/a

Table 2-14: Summary of Concept or Prototype Vehicles (EVs, HEVs, PHEVs, NEVs)[86,87,88]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
BYD	**E6**	Sedan	EV	Concept	www.byd.com
Cadillac	**Converj**	Sedan	PHEV	Concept	www.cadillac.com
Dodge	**Grand Caravan Hybrid**	Van	HEV	Concept	www.dodge.com
Ford	**Reflex**	Coupe	HEV	Concept	www.ford.com
Keio	**Eliica**	Coupe	EV	Concept	www.eliica.com/English/
Mercedes	**BlueZero**	Sedan	EV	Concept	mbusa.com
Mercury	**Meta One**	Van	HEV	Concept	www.mercuryvehicles.com
Mini Cooper	**Mini E**	Sedan	EV	Concept	www.miniusa.com
Mitsubishi	**iMiEV**	Sedan	EV	Concept	www.mitsubishicars.com
Mullen	**L1x-75**	Coupe	EV	Concept	www.mullenmotorco.com
Porteon	**EV**	Sedan	EV	Concept	www.porteon.net
Saab	**BioPower Hybrid**	Sedan	HEV	Concept	www.saabusa.com
Subaru	**R1E**	Coupe	EV	Concept	www.subaru.com
Toyota	**Volta**	Coupe	HEV	Concept	www.toyota.com/hsd
	A-BAT Hybrid Truck	Pickup	HEV	Concept	www.toyota.com/hsd
	Hybrid X	Sedan	HEV	Concept	www.toyota.com/hsd
	FT-EV	Coupe	EV	Concept	www.toyota.com/hsd
	Sienna Hybrid	Van	HEV	Concept	www.toyota.com/hsd
Velozzi	**Supercar**	Coupe	EV	Concept	www.velozzi.org
Venture	**VentureOne e50**	Coupe	NEV	Concept	xprizecars.com/2008/06/venture-vehicles-ventureone.php
Volvo	**3CCC**	Coupe	HEV	Concept	www.volvo.com
Wrightspeed	**X1**	Coupe	EV	Concept	www.wrightspeed.com

3. DEFINING THE HAZARD

In this section, the various hazards of concern to the emergency responder will be identified, and the loss history and a summary of applicable information resources for these applications will be offered.

Emergency Responder Hazard Assessment

Improvements in vehicle safety are one of the great public safety success stories of the twentieth century. During the 80-year period from 1925 to 2005 in the United States, the annual fatality rate has declined 92 percent from a rate of 18 per 100 million vehicle miles traveled to 1.45 per 100 million vehicle miles travelled.[89] Yet during this same period the number of drivers has increased 6-fold, the number of motor vehicles increased 12-fold, and the number of motor vehicle miles traveled has increased 24-fold.[90]

All motor vehicles on the road today have multiple potential hazards that may confront emergency responders. Some of these are independent of the type of propulsion system used, such as compressed gas or explosive cartridges used for air bags. The general hazards typically found in today's traditional motor vehicle are shown in Figure 3-1, Hazardous Materials Normally Found in Conventional-Fueled Vehicles.

Electric propulsion systems introduce new and possibly unanticipated hazards to emergency responders, although these do not include anything that members of the fire service would consider particularly challenging. For example, EVs and HEVs utilize high voltage power used for propulsion in conjunction with their low voltage electrical systems used for accessory lighting. The cabling for these high voltage systems were voluntarily colored bright orange for easy and consistent identification. In certain recent models cabling has appeared that, although it does not carry high voltage, still presents an appreciable and dangerous shock hazard, and these are identified using blue and yellow to color-code cables. In the meantime, additional shock hazards exist in all vehicles from certain features of the low voltage electrical system, such as, for example, the use of special high intensity discharge headlights.[91]

Identifying an EV or an HEV is not necessarily straightforward. There are direct means such as recognition of the specific model, or in some cases the "hybrid" logo is stated on the vehicle's exterior. Indirect means include a review of the instrumentation panel that reveals the vehicle's electrical propulsion system, or examining under the hood or trunk. Figures 3-2 through 3-9 provide illustrations of various EV and HEVs, and these demonstrate that other than the indication of *hybrid* nameplate on certain models, there is generally little exterior difference to distinguish a conventional-fueled vehicle from an EV or HEV.

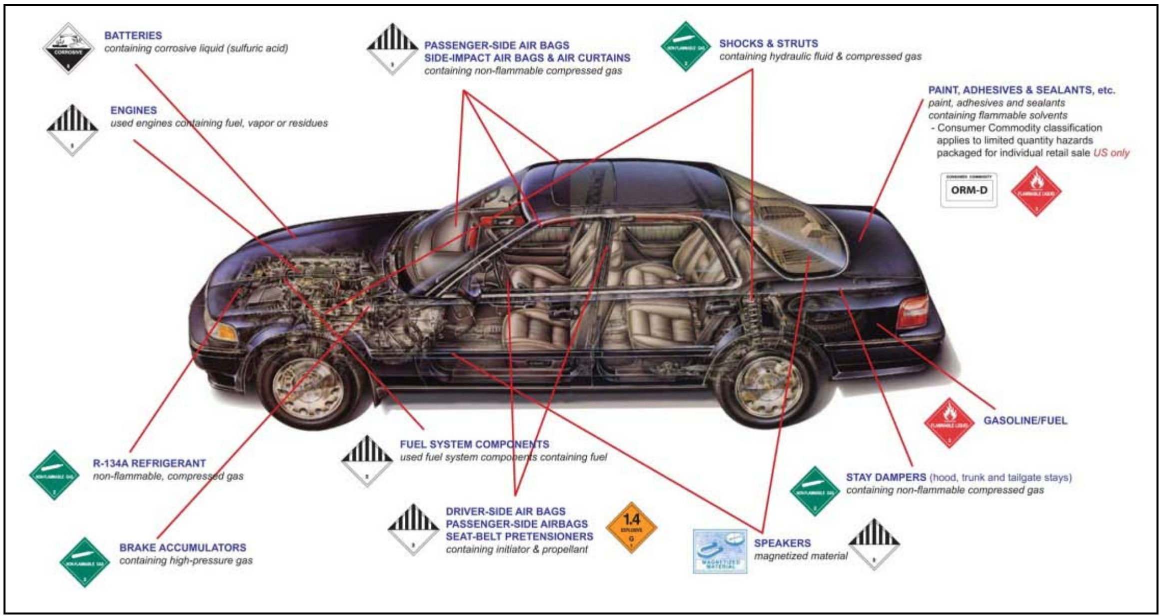


Figure 3-1: Hazardous Materials Normally Found in Conventional-Fueled Vehicles[92]
(Diagram courtesy of Pipeline and Hazardous Materials Safety Administration)

Conveniently, some models have very prominent indications that they are an HEV, such as the 2009 Cadillac Escalade (see Figure 3-7) and the 2009 Chevrolet Tahoe (see Figure 3-8) that have this etched in large type under the doors on each side. However, for an emergency responder even this is not consistent, as this external graphic on the 2009 Cadillac Escalade and 2009 Chevrolet Tahoe only appears on certain packages for these models.

Figure 3-2: 2009 Tesla Roadster Sport EV

Figure 3-3: 2009 Honda Insight HEV

Figure 3-4: 2009 Toyota Camry HEV

Figure 3-5: 2009 Toyota Highlander HEV

Figure 3-6: 2009 Toyota Prius HEV

Figure 3-7: 2009 Cadillac Escalade HEV

Figure 3-8: 2009 Chevrolet Tahoe HEV

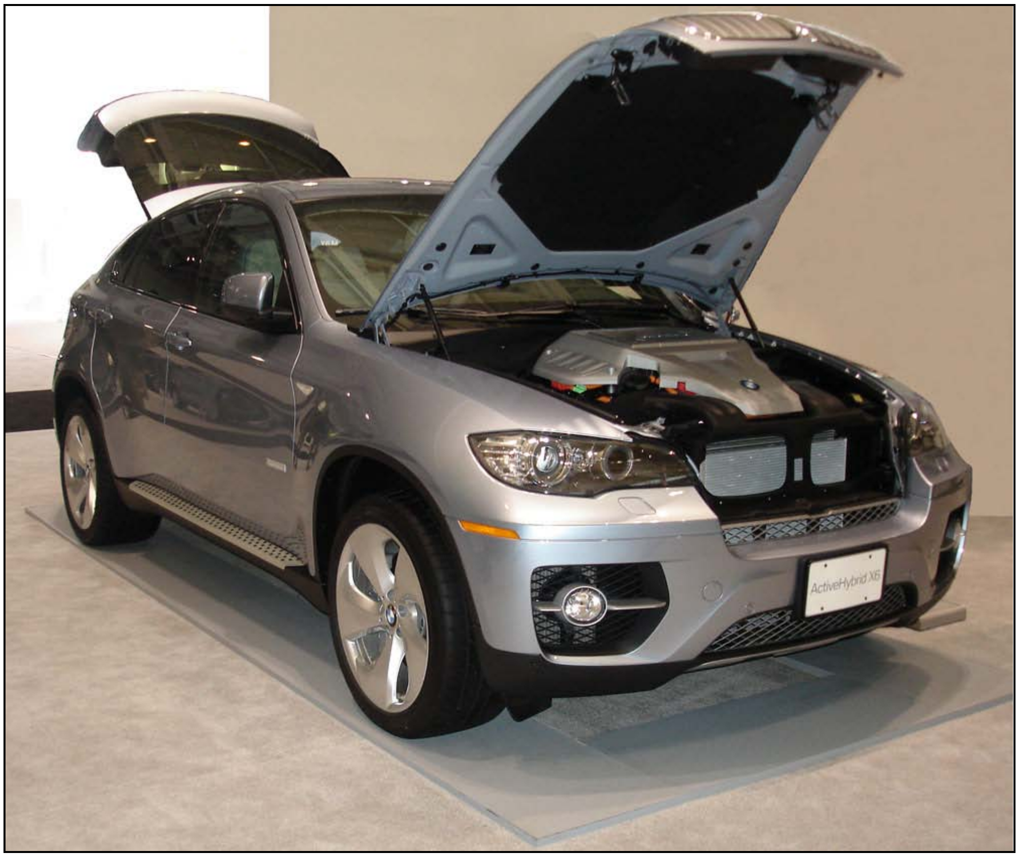


Figure 3-9: 2009 BMW X6 HEV

The specific hazards confronting the fire service with electric and hybrid electric vehicles are not much different than the hazards from conventionally fueled vehicles. Although different, they are not extraordinary in terms of their challenges to control and mitigate. Some fire service professionals have expressed their opinions that the specific hazards of EVs and HEVs are at times overemphasized, and can be readily managed with adequate preparation and common sense.[93]

One interesting concept being considered for quickly identifying vehicles in an emergency event is the implementation of a method for better using the VIN (vehicle identification number). This would require enhancing the VIN system to include information critical to emergency responders, better enabling first responders access to the VIN during an emergency, and providing them with an electronic means to access the critical operational information during the emergency.[94]

This approach was first proposed by Moore in 1999 as the VSDS concept. It is based on the similar widely recognized concept of MSDS (material safety data sheets) but instead for VSDS (vehicle safety data sheet).[95] This would be a type of vehicle placard system that would provide critical on-scene safety information to emergency response personnel. The vision is that this information would be provided on all vehicles in multiple standardized locations (e.g., on driver's visor), and could also be available in electronic format to on-scene emergency responders. Figure 21 provides an example of the VSDS concept implementation.

Figure 3-10: Example of VSDS Concept[96]
(on left, with standard visor warning label in center and typical garage door opener on right)
(Photo courtesy of Ron Moore)

Background on Electrical Hazards for Emergency First Responders

Each year close to 400 individuals among the general U.S. population suffer fatal electrocutions, and electrical shock while operating at an emergency scene is a realistic hazard.[97] Statistical data indicates that on average 40,270 fire fighters were injured during fireground operations in the United States annually from 2003 through 2006. Of these injuries, there were on average 215 fire fighters engaged in fireground operations whose injuries were due to "electric shock." Further, 50 of these annual injuries were considered moderate or severe injuries.[98] The data does not distinguish between events that were transportation related or involved structures and buildings.

How much electrical energy is required to cause harm to the human body? Electricity and electrical equipment is widespread in today's modern civilization. Each year in the U.S. among all industry sectors there are approximately 30,000 nonfatal electrical shock accidents.[99] Data from 1998 CDC/NIOSH summarizing electrocution fatalities in their data surveillance system indicates that during the decade of the 1980s approximately 7% of the average 6,359 annual traumatic work-related deaths were due to electrocution. This report also indicates that during the period from 1982 to 1994, twice as many fatal work-related electrocutions occurred with voltage levels greater than 600 volts.[100]

Understanding the dangers of electricity requires clarifying the terminology used to describe this danger. We often describe the magnitude of an electrical system in terms of *voltage* or *amperage*, and it is important to have a limited understanding of these terms. From a fire fighters perspective, the following describes these two terms:[101]

- Voltage –The electromotive force or potential difference, measured in volts. Voltage is the "pressure" that pushes an electrical charge through a conductor.
- Amperage or Current – The amount of electrical charge flowing past a given point per unit of time, measured in amperes or amps. Amperage is the measure of electrical current flow.

The flow of electrical energy in electrical wiring is analogous to the flow of water in a closed circuit of pipes. Hydraulics and the movement of water is a fundamental field of knowledge used by the fire service, and this visualization is useful to better comprehend the dangers of electricity. Instead of the transfer of water, electricity involves the transfer of electrons or other charge carriers. The voltage difference between two points corresponds to the water pressure difference between two points. If there is a difference between these two points, then flow will occur. Voltage is a convenient way of measuring the ability to do work.

The basic relationship between voltage and amperage is defined by Ohm's Law. This tells us that Volts x Amps = Watts, where wattage is the rate at which an appliance uses electrical energy. Wattage is considered the amount of work done when one amp at one volt flows through one ohm of resistance. The power generation of a photovoltaic system is usually described in terms of watts or kilowatts (1000 watts).[102]

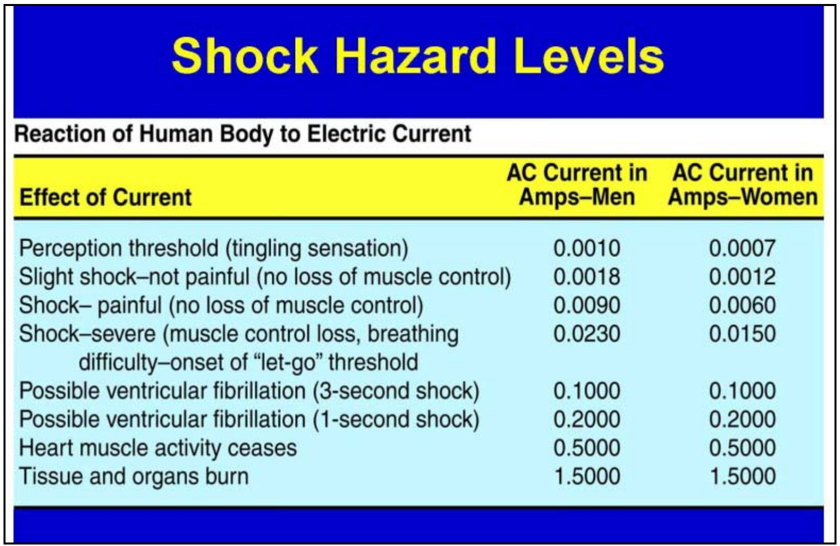
It is common to speak about the dangers of electricity in terms of voltage, but the amperage or current is the key measurement parameter of danger to humans. An electrical shock involving high voltage but very low current would be less dangerous than low voltage and high current. Table 3-1 provides some examples of the observable effects of electricity on the human body. The current required to light a 7½ watt, 120 volt lamp, if passed across the chest, is enough to cause a fatality.[103]

Table 3-1: Estimated Effect of 60 Hz AC Current on Humans[104,105]

Milliamperes	Observable Effect
15K/20K*	*Common fuse or circuit breaker opens*
1000	*Current used by a 100-watt light bulb*
900	Severe burns
300	Breathing stops
100	Heart stops beating (ventricular fibrillation threshold)
30	Suffocation possible
20	Muscle contraction (paralysis of respiratory muscles)
16	Maximum current an average man can release "grasp"
5	GFCI will trip
2	Mild shock
1	Threshold of sensation (barely perceptible)

*Note: 15 to 20 Amps (15,000 to 20,000 Milliamperes) is current required to open a common residential fuse or circuit breaker.

These electricity effects are also described in Figure 3-11, Human Body Reaction to Shock Hazards. Nearly all materials will conduct electrical current to some degree, and this includes the human body. Each situation involving an individual receiving an electrical shock is unique, and will depend on multiple factors that alter the manner in which the electricity passes through the human body and the detrimental effect that results. Variables affecting the physiological impact include: amount of current flowing through the body; length of contact time; travel path through the body; area of contact; pressure of contact; moisture of contact; body size and shape; and type of skin.[106]



Shock Hazard Levels

Reaction of Human Body to Electric Current

Effect of Current	AC Current in Amps–Men	AC Current in Amps–Women
Perception threshold (tingling sensation)	0.0010	0.0007
Slight shock–not painful (no loss of muscle control)	0.0018	0.0012
Shock– painful (no loss of muscle control)	0.0090	0.0060
Shock–severe (muscle control loss, breathing difficulty–onset of "let-go" threshold	0.0230	0.0150
Possible ventricular fibrillation (3-second shock)	0.1000	0.1000
Possible ventricular fibrillation (1-second shock)	0.2000	0.2000
Heart muscle activity ceases	0.5000	0.5000
Tissue and organs burn	1.5000	1.5000

Figure 3-11: Human Body Reaction to Shock Hazards[107]

EVs and HEVs typically include high voltage batteries, and the presence of high voltage components creates a possible electrocution hazard (static voltage levels between 36V to 330V with operational voltages up to 600V) to emergency personnel, especially before they realize the vehicle is a hybrid model. The following are some general considerations for emergency responders addressing an event involving these vehicles:[108]

- Always assume the vehicle is powered-up despite no engine noises, and always use wheel chocks.
- Put vehicle in park, turn ignition off, and remove key to disable the high voltage system.
- Never touch, cut, or open any orange cable or components protected by orange shields.
- Remain a safe distance from vehicle if it is on fire.
- Consider the electrical system unsafe for a full 10 minutes after ignition shut-down.
- Contact local auto dealerships for more information about their hybrid vehicles.

The term *high voltage* is defined differently depending on the particular application, and understandably this creates confusion among emergency responders who must handle emergencies with electrical equipment. For example, voltage ratings for buildings and structures in the built infrastructure treat high voltage as being any voltage exceeding 600 volts, based on Article 490 of the National Electrical Code.[109] Voltage ratings for electrical equipment generally conforms to the ANSI C84.1 standard, which considers low voltage as 600 volts and below.[110] Figure 3-12 illustrates a fast charging station that uses higher voltage to charge an EV or PHEV.

Figure 3-12: EV Fast Charging Station

(Photo courtesy of NREL Photographic Information Exchange)

Vehicle electrical systems generally conform to the applicable SAE (Society of Automotive Engineers) related standards. High voltage is indicated as any wiring system which contains one or more circuits operating between 60 Volts DC or Volts AC RMS, and 600 Volts DC or Volts AC RMS.[111] Potentially hazardous voltage means any voltage levels that can harm humans through electric shock.[112] Generally recognized vehicle electrical current classes are:

- Low – Up to and including 30 Volts DC or 15 Volts AC,
- Intermediate –Greater than 30 Volts DC or 15 Volts AC and less than and including 60 Volts DC or 30 Volts AC
- High –Greater than 60 Volts DC or 30 Volts AC

These classifications are not universally used; an example is the General Motors BAS system that uses an alternative classifying system. Despite the lack of universal definitions of high, medium and low voltage, from the perspective of emergency responders, any voltage level that can cause injury or worse is of paramount concern.

Loss History and Data

Emergencies involving motor vehicles are not uncommon. In 2007, there were 6,024,000 crashes in the United States, resulting in 2,491,000 injuries and 41,059 fatalities.[113] Automobile collisions continue to be a major societal concern and are a common emergency event for fire service responders.

How do crashes and fires involving EVs and HEVs compare with other types of vehicles? Unfortunately, this type of statistical data that would distinguish EVs and HEVs from conventional vehicles and other alternative fuels vehicles is not yet readily available. This situation is expected to change as these newer designs become more common and realistic statistical sampling can be provided. At this time, the overall loss information discussed herein includes vehicles by class rather than fuel type or type of power train.

Some of these motor vehicle collisions in the recorded data involved fires. Motor vehicle fires often occur as a result of collisions, but they also occur in other situations such as parked or idling vehicles. Based on 2008 data, in the United States there was one vehicle fire reported on average of every 134 seconds. The U.S. fire service responded to 236,000 vehicle fires in 2008 resulting in 365 civilian fire deaths, 1,065 civilian fire injuries, and 1.5 billion dollars in property damage.[114] The magnitude of the vehicle fire situation in the United States, focusing on all types of vehicles, is summarized in the following four figures:

- Figure 3-13, U.S. Vehicle Fires by Year;
- Figure 3-14, U.S. Vehicle Fire-Related Deaths by Year;
- Figure 3-15, Highway Vehicle Fires and Deaths by Fire Causal Factor; and
- Figure 3-16, Area of Origin in Vehicle Fires, by Fire Causal Factor

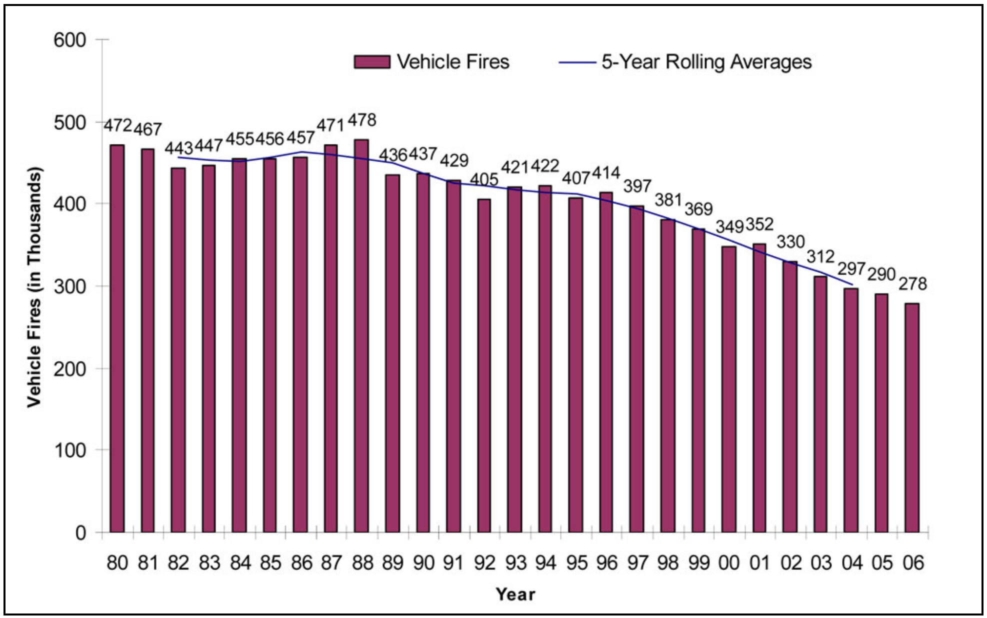


Figure 3-13: U.S. Vehicle Fires by Year[115]

Selected fire event summaries are available that describe specific emergency scenarios involving EVs or HEVs. The National Fire Fighter Near-Miss Reporting System describes several incidents involving HEVs, and they are mentioned here for purposes of providing detailed examples. They provide grouped reports with each containing details of several dozen selected events involving fire fighters exposed to electrical shock or encountering a notable hazard at a vehicle incident, such as unexpected vehicle movement.[119]

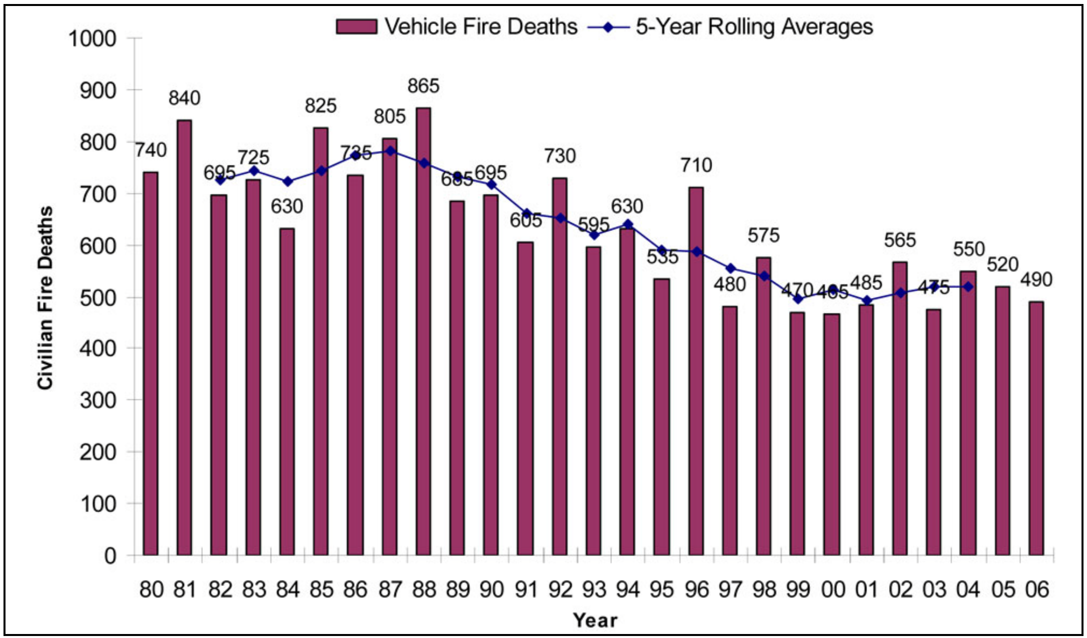


Figure 3-14: U.S. Vehicle Fire Related Deaths by Year[116]

One incident was a major motor vehicle accident involving several vehicles including a hybrid, with extrication but no fire. Initially it was thought that the HEV was not running because it was quiet, but this was not the case and fortunately it was disengaged prior to any vehicle movement during the extrication process.[120]

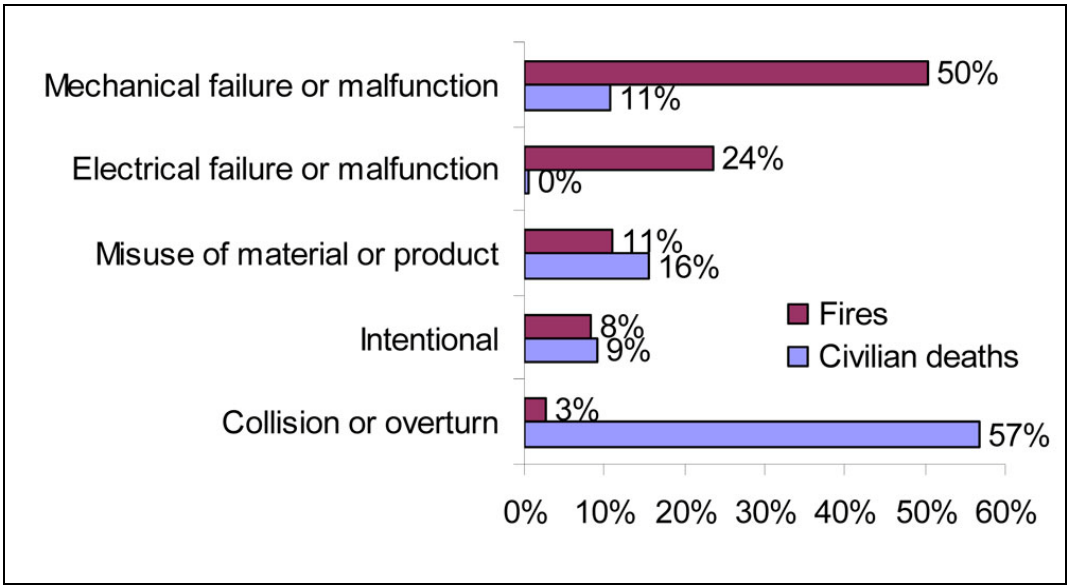


Figure 3-15: Highway Vehicle Fires and Deaths by Fire Causal Factor[117]

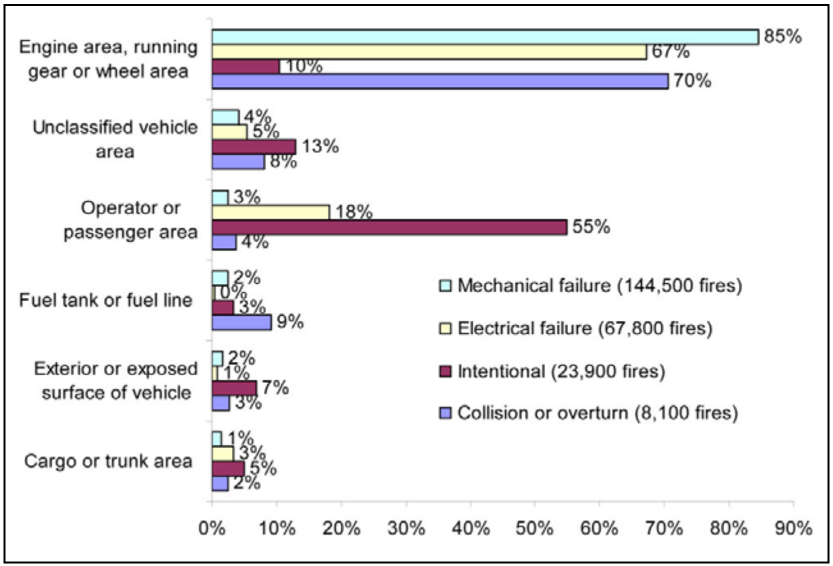


Figure 3-16: Area of Origin in Vehicle Fires, by Fire Causal Factor[118]

Another incident was similar but involved four vehicles wedged together in a rear-end collision, making engine and truck access impossible until the vehicles were separated for removal. As the vehicles were being loaded by the tow truck operator the hybrid vehicle started smoking since it was still active, but fortunately it had already been secured and was then rendered inoperable.[121]

Information Resources

Useful data and information is included in a series of handbooks and compilations of data by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. These contain helpful information and data addressing EVs and HEVs that are updated on a regular basis. Some examples include the following:[122]

- Buildings Energy Data Book: www.btscoredatabook.net
- Power Technologies Energy Data Book: nrel.gov/analysis/power_databook
- Transportation Energy Data Book: cta.ornl.gov/data

Illustrations are a critical aspect of training programs for emergency responders, and a valuable source of useful pictures on a wide range of alternative energy related topics including electric vehicles is the NREL PIX (National Renewable Energy Laboratory Picture Information Exchange). This website is located at www.nrel.gov/data/pix/ and offers a substantial library of illustrations that can be freely downloaded and used, and also provides a service for obtaining high resolution pictures if needed.

Additional sources of information are contained in the technical requirements of internationally recognized codes and standards. These address emergency responder concerns for EVs and

HEVs either in whole or in part. They provide information about not only the vehicle itself, but of equal importance, the charging stations and other similar auxiliary support equipment. Figure 3-17 illustrates a charging stations arrangement involving EV taxis at an airport.

Figure 3-17: EV Taxis at a Charging Station

(Photo courtesy of NREL Photographic Information Exchange)

Table 3-2 provides a summary of technical codes and standards that address safety design requirements directly relating to EVs and HEVs.[123] These documents are typically in constant revision cycles, resulting in new and/or updated editions on a regular basis.

Table 3-2: Summary of Technical Codes and Standards Addressing Design of EVs and HEVs[124]

Document #	Document Title/Section
IEC 61851-1	Electric Vehicle Conductive Charging System – *Part 1: General Requirements*
IEC 61851-21	Electric Vehicle Conductive Charging System – *Part 21: Electric Vehicle Requirements for Conductive Connection to an ac/dc Supply*
IEC 61851-22	Electric Vehicle Conductive Charging System – *Part 22: Electric Vehicle Charging Station*
ISO/FDIS 6469-1 2009(E)	Electrically propelled road vehicles - Safety specification - *Part 1 On-board Rechargeable Energy Storage System (RESS)*
ISO/FDIS 6469-2 2009(E)	Electrically propelled road vehicles - Safety specification - *Part 2 Vehicle Operational Safety Means and Protection against Failures*
ISO/CD 6469-3.3	Electrically propelled road vehicles - Safety specification - *Part 3 Protection of Persons Against Electric Shock*
ISO/CD 12405-1	Electrically propelled road vehicles - Test specification for lithium-ion traction battery packs and systems - *Part 1 High Power Applications*
ISO/WD 23274-2	Hybrid-electric road vehicles - Exhaust emissions and fuel consumption measurements - *Part 2 Externally Chargeable Vehicles*
NFPA 70	*National Electrical Code* (NEC), Article 625, Electric Vehicle Charging System Equipment
NFPA 70	*National Electrical Code* (NEC), Article 626, Electrified Truck Parking Spaces
SAE J-1634	*Electric Vehicle Energy Consumption and Range Test*

Document #	Document Title/Section
SAE J-1711	*Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles*
SAE J-1715	*Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology*
SAE J-1766	*Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing*
SAE J-1772	*SAE Electric Vehicle Conductive Charge Coupler*
SAE J-1773	*SAE Electric Vehicle Inductively-Coupled Charging*
SAE J-1797	*Recommended Practice for Packaging of Electric Vehicle Battery Modules*
SAE J-1798	*Recommended Practice for Performance Rating of Electric Vehicle Battery Modules*
SAE J-1850	*Class B Data Communications Network Interface*
SAE J-2288	*Life Cycle Testing of Electric Vehicle Battery Modules*
SAE J-2289	*Electric-Drive Battery Pack System, Functional Guidelines*
SAE J-2293 Part 1	*Energy Transfer System for EV Part 1, Functional Requirements and System Architecture*
SAE J-2293 Part 2	*Energy Transfer System for EV Part 2, Communications Requirements and Network Architecture*
SAE J-2344	*Guidelines for Electric Vehicle Safety*
SAE J-2380	*Vibration Testing of Electric Vehicle Batteries*
SAE J-2464	*Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*
SAE J-2711	*Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy Duty Vehicles*
SAE J-2758	*Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle*
SAE J-2836 Part 1	*Use Cases for Communications between Plug-In Vehicles and the Utility Grid*
SAE J-2836 Part 2	*Use Cases for Communications between Plug-In Vehicles and the Supply Equipment (EVSE)*
SAE J-2836 part 3	*Use Cases for Communications between Plug-In Vehicles and the Utility grid for Reverse Flow*
SAE J-2841	*Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using 2001 U.S. DOT National Household Travel Survey Data*
SAE J-2847 Part 1	*Communications between Plug-In Vehicles and the Utility Grid*
SAE J-2847 Part 2	*Communication between Plug-in Vehicles and the Supply Equipment (EVSE)*
SAE J-2847 Part 3	*Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow*
SAE J-2889	*Measurement of Minimum Sound Levels of Passenger Vehicles*
SAE J-2894 Part 1	*Power Quality Requirements for Plug-In Vehicle Chargers - Requirements*
SAE J-2894 Part 2	*Power Quality Requirements for Plug-In Vehicle Chargers - Test Methods*
SAE J-2907	*Power Rating Method for Automotive Electric Propulsion Motor and Power Electronics Sub-System*
SAE J-2908	*Power Rating Method for Hybrid-Electric and Battery Electric Vehicle Propulsion*

Several important initiatives are under way to provide ongoing coordinated operational and training information for emergency first responders dealing with EV and HEV emergencies. These will ultimately serve as important conduits for delivering critical information for emergency first responders. This includes a DOE-funded 3-year initiative led by NFPA (National Fire Protection Association) in partnership with multiple other organizations, including: AAM (Alliance of Automobile Manufacturers); IAFC (International Association of Fire Chiefs); IAFF (International Association of Fire Fighters); IFMA (International Fire Marshals Association);

Metropolitan Fire Chiefs; NAFTD (North American Fire Training Directors); NASFM (National Association of State Fire Marshals); NFPA Fire Service Section; NREL (National Renewable Energy Laboratory); NVFC (National Volunteer Fire Council); and USFA (U.S. Fire Administration).[125]

An earlier initiative that had been focusing on providing specific technical vehicle information for emergency first responders was ComCare, a nonprofit organization composed of certain emergency response organizations. They were developing a Vehicle Rescue Portal and Vehicular Emergency Data Set (VEDS) to provide access to technical data about new automotive technologies, and provide guidance on how to respond if these vehicles are involved in a collision or fire.[126] However, their current operating status is unclear, and there is recent indication that they are transitioning into a new organization known as “Advanced Emergency Communications Coalition”, which may or may not continue the VEDS initiative.

An important source of emergency response information is from the individual automakers, who typically provide information about their vehicles for emergency first responders. This is especially helpful for new technologies that raise questions about the proper tactics and strategies for handling a particular emergency situation. This information is reviewed in greater detail later in this report.

The fire service literature includes multiple published articles that specifically address EV and HEV emergency situations. This information includes the handling of extrication following a crash and fires. A summary of the readily available literature addressing fire service concerns and electric and hybrid electric vehicles is provided by Table 3-3, Literature Review Summary for Electric Vehicles and the Fire Service.

Table 3-3: Literature Review Summary for Electric Vehicles and the Fire Service

	Title	**Publication**	**Author(s)**	**Year**	**Vol/Iss**	**Pg(s)**	**Format**	**Comment**
1	Electric and Hybrid Electric Vehicle Emergency Rescue Training		ACTS Foundation	1993			Video	Instructor’s manual addressing electric and hybrid electric vehicle emergency rescue training
2	*Emergency Rescue Training Program Developed for Electric Vehicles*	Fireman's Journal	ACTS Foundation	1994 Spring	12/2	29	Article	Training program for rescue from electric-powered vehicles
3	*Electric Vehicles - What Hazards Do They Pose to Emergency Responders?*	Health & Safety	Skelton, D.E.	1996 Feb	7/2	6-7	Article	Concerns about electric vehicles based on proposed CARB rules
4	*Emergency Response to Electric Vehicles - Student Manual*	Chang, E., Rawson, M., Slaughter, R.,	CA Dept of Forestry & Fire Prot Office of State FM	1997 Mar			Book	

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
5	*Emergency Response to Electric Vehicles - Instructor Guide*		CA Dept of Forestry & Fire Prot Office of State FM	1997 Jun			Book &Video	
6	*The VSDS Proposal: Providing Critical Data To Rescue Personnel*	Firehouse	Moore, R.E.	1999 July	24/7		Article	Proposal for approach similar to MSDS, but instead for Vehicle Safety Data Sheet
7	*Electrical Systems: Part 1*	Firehouse	Moore, R.E.	2000 May	25/5	31-32	Article	Part 1 of 2 on electrical shutdown and vehicle battery locations
8	*Electrical Systems: Part 2*	Firehouse	Moore, R.E.	2000 June	25/6	25-26	Article	Part 2 of 2 on electrical shutdown and vehicle battery locations
9	*Alternative Fuel Vehicles (And How They'll Affect Rescuers)*	National Fire & Rescue	Uttley, M.	2001 Mar/ April	25/2	37-42	Article	Review of multiple types of hybrid vehicles for rescuers
10	*The Thoughtful Rescuer*	Fire-Rescue Magazine	Kidd, J. S.	2001 June	19/6	20-21	Article	Review of strike zone and other extrication concepts
11	*Hybrid Vehicles: Part 1 - What Are Hybrid Vehicles? How Do They Work?*	Firehouse	Moore, R.E.	2001 July	26/7	112	Article	Part 1 of 3 providing a review of current and anticipated hybrid-fueled vehicles
12	*Hybrid Vehicles: Part 2 – Emergency Procedures*	Firehouse	Moore, R.E.	2001 Aug	26/8	35-36	Article	Part 2 of 3 describing the emergency procedures that should be used for a hybrid vehicle fire
13	*Hybrid Vehicles: Part 3 - Rescue Operations*	Firehouse	Moore, R.E.	2001 Sept	26/9	35-36	Article	Part 3 of 3 focusing on extrication and rescue from a hybrid vehicle
14	*Hybrid Vehicles*		Moore, R.E.	2002			CDRom	
15	*Hybrid Vehicles*		Moore, R.E.	2002			Book	Published by Plano TX FD, with particular focus on Toyota Prius and Honda Insight
16	*Vehicle Rescue And Extrication*		Moore, R.E.	2002	2nd edition		Book	Book on vehicle rescue
17	*Toyota Prius Gasoline-Electric Hybrid Emergency Response Guide (Revised), 2002*		Toyota	2002			Book	
18	*Vehicle Extrication*		Stearns, R.	2002			Loose-leaf	Published by City of Wichita KS FD

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
19	*Vehicle Extrication : Hybrid Vehicles*		Stearns, R.	2002			CDRom	
20	*Hybrids Go Mainstream: Tips on Spotting & Dealing* with These New Machines	Fire Rescue Magazine	Kidd, S.	2002 June	20/6	22-23	Article	Summary of alternative-fuel and hybrid-fueled cars as of 2002
21	*The Dangers of Hybrids*	Law Enforcement Technology	Hayes, P.	2002 Sept	29/9		Article	
22	*Toyota FCHV (Fuel Cell Hybrid Vehicle) Emergency Response Guide*		Toyota Motor Corp	2003			Book	
23	*Hybrid Vehicle Safety Issues*	Fire Fighters Guidance Note #6-19	Ontario Fire Service Advisory Committee	2003			Book	Brief review of hazards involving hybrid vehicles
24	*Now Showing in Your District: Hybrid Vehicles!*	Size Up	Wimer, D.R.	2004 Fall		58-59	Article	Basic steps to take for handling hybrids
25	*Hybrid Vehicles: Safe Or Sorrowful?*	Size Up	Wimer, D.R.	2004 Winter		58-60	Article	Latest technology minimizing shock hazard to fire fighters
26	Auto Design and Extrication Forum, 2005		State Farm Insurance Companies	2005			DVD	
27	*Vehicle Extrication: A Practical Guide*	PennWell Corp	Anderson, B.G.	2005			Book	Detailed information for extrication from all types of vehicles
28	*The Power Of Cooperation: First Responders, Utility Workers Face New Electrical Hazards*	Safety & Health	Parker, J.G.	2005 Jan	171/1	26-31	Article	
29	*Alternate-Fueled Vehicles*	Firehouse	Blatus, R.J., Richardson, T.J	2005 March		88	Article	Addresses hybrid and alternative-fuel vehicle fire hazards
30	*Pry, Pry Again*	Fire Chief	Hoffman, T.	2005 May	49/5	72-77	Article	Addresses extrication from hybrid vehicles involving multiple airbags and extensive restraint systems
31	*Hybrids: How Are They Different?*	Siren	Mazurkiewicz, G.	2005 Oct		2	Article	Review of emergency responder concern with electric vehicles
32	*Meet Ford's Hybrid SUV*	Advanced Rescue Technology	Long, D.	2005 Dec / 2006 Jan	8/6	22-25	Article	

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
33	Auto Design And Extrication Forum, 2006		State Farm Insurance Companies	2006			DVD	
34	*Hybrid Electric Vehicle Safety And Extrication: 2005/2006 Model Year Update*		Access Training Systems Int'l Media Group	2006			DVD	Published by ATSI Media Group
35	Vehicle Extrication: 2006			2006			DVD	Part 3 on hazard control and safety
36	*A Guide to New Rides*	Fire Rescue Magazine	Uttley, M.	2006 March	24/3	72-78	Article	Glimpse of new technology that could affect vehicle rescue from the 2006 North Am. Int'l Auto Show
37	*Hybrid Vehicle Safety*	Volunteer Firefighter	Shaw, R.	2006 April	77/4	32-34	Article	Part 1 of 2 with a review of hybrid vehicle safety concerns
38	*Critical Infrastructure Protection*	FDSOA Health & Safety		2006 Jun	17/6	10	Article	An update of hybrid cautions from a 2005 USFA Info-gram
39	*Emergency Procedures For Gasoline-Electric Hybrid Vehicles*	American Heat	Trinity Workplace Learning	2006 Oct			Video	
40	*Gasoline-Electric Hybrid Vehicles*	Firehouse	Moore, R.E.	2006 Nov	31/11	43-44	Article	Hands-on training exercise on hybrid vehicles in accordance with NFPA 1670
41	*Hybrid Vehicles: What's All The Buzz About?*	Fire Engineering	Dalrymple, D.	2006 Nov	159/11	24-29	Article	Review of current and future hybrid vehicle designs for rescuers
42	*Hybrid Vehicles*	Firehouse	Moore, R.E.	2006 Dec	31/12	39-40	Article	Review of rescue from 2 hybrid pickups
43	Hybrid Emergency Response Information: Training Presentation, 2007			2007			CDRom	
44	*Hybrid Vehicles*	WNYF	Miles, J.M.	2007	162/4	9-10	Article	
45	*PPE For Hybrid Vehicles: What Do We Need?*	Size Up	Wimer, D.R.	2007	3	50-51	Article	PPE recommendations for addressing hybrids
46	*The Hybrid Electric Bus*	WNYF	Doda, M.	2007	162/4	11-12	Article	
47	*Vehicle Fire Suppression Research Needs*	NISTIR 7406	Hamins, A.	2007 Mar			Report	NIST BFRL Publication on post-collision vehicle fire research needs

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
48	*Fire Safety of the Traveling Public and Firefighters for Today's and Tomorrow's Vehicle Fleet*	FPRF Report	Milke, J.A., Sunderland , P.B., Levy, K.M. Ontiveros, V.L., Carey, A.C.	2007 Apr			Report	Review of statistical data and mitigation strategies for vehicle fires
49	Vehicle Electrical Systems: Power Backfeeding	Firehouse	Moore, R.E.	2007 June	32/6	35-36	Article	Powering down a vehicle electrical system when portable devices are plugged -in
50	Hybrid Vehicle Update – Part 1 Color-Coding High Voltage Cables & Connectors	Firehouse	Moore, R.E.	2007 July	32/7	43-45	Article	Part 1 on color-coding of hybrid vehicle high-voltage cables & connectors
51	*Compound Factors*	Fire Chief	Emery, J.D.	2007 Aug	51/8	92-95	Article	Focus on extrication and electrocution hazard of hybrid vehicles
52	*Hybrid Vehicle Update 2007 – Part 2*	Firehouse	Moore, R.E.	2007 Aug	32/8	45-46	Article	Part 2 on safety considerations at gasoline-electric hybrid vehicle incidents
53	*Hybrid Hints And Hazards*	Fire Fighting in Canada	Methner, P.	2007 Nov	51/7	36-40	Article	Review of size up, cutting power, and extrication methods for hybrid vehicles
54	*Don't Get Shocked: Hybrid Vehicle Emergency Procedures Update*	Size Up	Moore, R.E.	2008	08/3		Article	Update on emergency procedures for hybrids
55	*Hybrid School Buses: Response Considerations*	Fire Engineering	Hollins, L.T.	2008 Jan	161/1	107-108	Article	Case study review of a hybrid school bus
56	*Extrication Tips: Hybrid Vehicles*	Pennsylvania Fireman	Schmitz, R.	2008 Feb	71/5	110-112	Article	Comparison of hybrid vehicle rescue with conventional vehicles
57	*Instructor Guide: Rescue Company Operations - Hybrid Vehicles*	Drill of the Month	Peterson, E.	2008 July		6	Article	
58	*U.S. Vehicle Fire Trends and Patterns*	NFPA Fire Analysis & Research Div.	Ahrens, M.	2008 July			Report	Statistical information on U.S. vehicle fire problem
59	*Two-Mode Hybrid Vehicles*	Firehouse	Moore, R.E.	2008 Sept	33/9	37-39	Article	Focus on GMC *Yukon* and Chevy Tahoe two-mode hybrid vehicles

	Title	Publication	Author(s)	Year	Vol/Iss	Pg(s)	Format	Comment
60	*Hybrid Vehicle Rescue: Replacing Fear with Knowledge*	Carolina Fire Rescue EMS Journal	Shaw, R.	2008 Winter	22/3	44-71	Article	Part 1 of 2: Review of basics for emergency responders
61	*Hybrid Vehicle Rescue: Replacing Fear with Knowledge*	Carolina Fire Rescue EMS Journal	Shaw, R.	2008 Spring	22/4	12-35	Article	Part 2 of 2: Review of basics for emergency responders
62	*Fighting Hybrid Vehicle Fires*	Carolina Fire Rescue EMS Journal	Shaw, R.	2008 Summer	23/1	9-13	Article	Firefighting operations for hybrid vehicles
63	*NiMH Battery Spills and Exposures*	Carolina Fire Rescue EMS Journal	Shaw, R.	2008 Fall	23/2	20-71	Article	Details for fire service handling of NiMH batteries
64	*Hybrid Vehicle Incidents: Auto Industry's 'Green Movement' Creates Gray Area For Some Emergency Personnel*	Size Up	Wimer, D.R	2009	3	30-32	Article	Team approach using stabilization, power down, extrication, and decontamination
65	*Best Practices for Today's Extrication*	Size Up	Dalrymple, D.	2009	3	33-35	Article	Review of technology and operational facets of vehicle extrication
66	*Rescue and Alternative Vehicle Power*	Fire Engineering	Dalrymple, D.	2009 Apr	162/4	151-152	Article	Review of rescue concerns with alternative-fueled vehicles, including electric hybrids
67	*Hybrid Vehicles: Separating Fact From Fiction*	Fire Engineering	Emery, J.D.	2009 July	162/7	73-82	Article	Review of current hybrid vehicles and those anticipated through 2011

4. OVERVIEW OF FIRE SERVICE OPERATIONAL MATERIALS

Training and education are important in preparing fire fighters to properly perform their assigned tasks. Arguably of greater importance, however, are the operational guidelines and operational procedures use by fire departments to perform their duties to mitigate an emergency situation. Standard operating procedures (SOPs) and standard operating guidelines (SOGs) are widely used in today's fire service.

The terms *procedure*s and *guidelines* are sometimes used interchangeably. However, in fire service parlance they are considered to be different. Procedures imply relatively inflexible instructions, prescriptive task steps, and appreciable detail. In contrast guidelines are more performance oriented and imply discretion in performing the required tasks.[127] A sample of a Standard Operating Guideline is offered in Annex D.

There is significant overlap in the interpretation and final implementation of these descriptors, and ultimately it can sometimes be difficult to distinguish the difference between them. Multiple precise definitions can be found in the fire service literature. As one example, the following definitions are from the 2008 edition of NFPA 1521, *Standard for Fire Department Safety Officer*:

> Standard Operating Guideline: A written organizational directive that establishes or prescribes specific operational or administrative methods to be followed routinely, which can be varied due to operational need in the performance of designated operations or actions. (Note: Standard operating guidelines allow flexibility in application.)[128]
>
> Standard Operating Procedure: A written organizational directive that establishes or prescribes specific operational or administrative methods to be followed routinely for the performance of designated operations or actions. (Note: The intent of standard operating procedures is to establish directives that must be followed.)[129]

The wide range of possible unpredictable emergency scenarios requires a degree of flexibility in terms of written procedures, but conversely too much flexibility and discretion reduces control and increases the likelihood of mistakes. Litigation sometimes provides the basis for interpreting the difference between procedures and guidelines, but the courts tend to ignore actual terminology and focus on content. They tend to consider liability based on factors such as: national standards and other recognized regulatory requirements, adequacy of training activities; demonstration of training competence; procedures for monitoring performance; unique needs of the fire department; and procedures for ensuring compliance.[130]

Actual fire service education and training materials can be obtained from a number of sources. General emergency responder operational materials are readily available, and these can be adapted and used directly by members of the fire service. This includes, for example, the training manuals provided since 1932 by the International Fire Service Training Association, fire service training materials provided by Jones and Bartlett Publishers, and various books and publications provided through Delmar Learning.[131,132,133] Specific details of these organizations include the following:

International Fire Service Training Association (IFSTA): The mission of IFSTA is to identify areas of need for training materials and foster the development and validation of training materials for the fire service and related areas. With origins that are traced back to 1934, this association of fire service personnel provides oversight and validation of the manuals, curricula, training videos, CD-ROMs, and other materials developed by Fire Protection Publications (FPP). FPP is a department of Oklahoma State University and serves as the headquarters for IFSTA in Stillwater, Oklahoma.[134]

Jones and Bartlett Publishing (J&B): J&B publishes an extensive line of training materials for the fire service, including comprehensive online resources for fire service students and instructors. As an independent publisher headquartered in Sudbury MA, they are the seventh largest college publisher in the United States, publishing training materials as professional and reference books as well as a variety of multimedia and online products. The content for their training materials is developed in collaboration with the International Association of Fire Chiefs and the National Fire Protection Association.[135]

Delmar Learning: Delmar is a sub-group within Cengage Learning and they offer a portfolio of emergency services educational and training materials. Headquartered in Clifton Park NJ, their products include printed books, multimedia, online solutions, certification tests, reference products, instructor teaching and preparation tools.[136]

A key federal government organization serving as an external training source for fire departments is the National Fire Academy (NFA) of the USFA.[137] The NFA is the Fire Administration's training delivery arm and is located in Emmitsburg, Maryland. The creation of the NFA has its genesis in the landmark report *America Burning* written in 1973, which recommended the establishment of a "National Fire Academy for the advanced education of fire service officers and for assistance to state and local training programs".[138]

With more than three decades of operation, the NFA has earned the respect of the fire service and provides an important stabilizing influence that helps to unite the fire service on the myriad of specific training topics. As a central focus point for the development and refining of fire service training materials, the NFA works closely with not only the vast range of local and regional fire departments throughout the country, but equally with the various national organizations that administer important sub-components of the training infrastructure. At the state level the NFA works closely with the state fire training directors through their association the North American Fire Training Directors (NAFTD).

The NFA provides an important forum for the centralized development, refinement, and dissemination of fire service training materials on specific topics. An alternative to the training courses delivered on-site at the NFA is to build special topic curricula, which are then made available for internal fire department training activities through NFA "Endorsed Courses".[139] The NFA also provides hand-off training programs for individual training academies that are usually based on two-days worth of content.

These Endorsed Courses at NFA provide a mechanism for outside organizations to cultivate and promote the development of applicable, state-of-the-art, accurate, useful and timely training information. As a specific example worthy of consideration, the training information contained in U.S. DOE on-line training packages such as "Hydrogen Safety for First Responders" and "Introduction to Hydrogen for Code Officials" may be candidates for material used in NFA endorsed courses.[140,141]

One NFA activity that serves a critical role in disseminating training information to the various state and local training agencies is the *Training Resources and Data Exchange (TRADE)* program.[142] This is a network of the state fire service training systems, along with the senior executive training officers from the Nation's largest fire departments protecting populations greater than 200,000 and/or who have more than 400 uniformed personnel. As a regionally based network established in 1984, TRADE facilitates the exchange of fire-related training information and resources among government organizations at the local, state and federal levels.

The TRADE system operates using geographic regions that correspond to the ten FEMA regions, with coordinated networking within the respective regions and between regions. The National Fire Academy works closely with TRADE on various training details, and refers to them for functions such as the review of NFA Endorsed Courses. Specifically, TRADE serves their mission through the following:

- Identifying regional fire, rescue, and emergency medical services training needs;
- Identifying applicable fire-related training and education national trends;
- Exchanging and replicating training programs and resources within regions; and
- Provide annual regional assessments of fire training resource needs to NFA.

Aside from general information for addressing vehicle fires or vehicle rescue, most automobile manufacturers provide emergency response guides for their vehicles available through the internet. Table 4-1 provides the web links to Emergency Response Guides in PDF format for selected HEVs produced in the United States.

Table 4-1: Web Links for Selected HEV Emergency Response Guides

Cadillac Escalade Hybrid (2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Silverado%20&%20Sierra%20Hybrid%20ERG%20(2nd%20Gen)%20&%20Yukon,%20Tahoe,%20Escalade.pdf
www.emergencytrainingsolutions.com/downloads/ERGs/Chevy%20Tahoe%20-%20GMC%20Yukon%20-%20Cadillac%20Escalade%20Quick%20Reference%20Sheet.pdf

Chevrolet Malibu Hybrid (2008):
www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Aura%20and%20Chevy%20Ma

libu%20Hybrid%20ERG.pdf
www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Aura%20and%20Chevy%20Malibu%20Hybrid%20Quick%20Reference%20Guide.pdf

Chevrolet Silverado Hybrid, 1st Generation (2004):
www.emergencytrainingsolutions.com/downloads/ERGs/Silverado%20&%20Sierra%20Hybrid%20ERG%20(1st%20Generation).PDF

Chevrolet Silverado Hybrid, 2nd Generation (2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Silverado%20&%20Sierra%20Hybrid%20ERG%20(2nd%20Gen)%20&%20Yukon,%20Tahoe,%20Escalade.pdf

Chevrolet Tahoe Hybrid (2008):
www.emergencytrainingsolutions.com/downloads/ERGs/Chevy%20Tahoe%20-%20GMC%20Yukon%20ERG.pdf
www.emergencytrainingsolutions.com/downloads/ERGs/Chevy%20Tahoe%20-%20GMC%20Yukon%20-%20Cadillac%20Escalade%20Quick%20Reference%20Sheet.pdf

Chrysler Aspen HEV (2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Dodge%20Durango%20-%20Chrysler%20Aspen%20Hybrid%20ERG.pdf

Dodge Durango HEV (2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Dodge%20Durango%20-%20Chrysler%20Aspen%20Hybrid%20ERG.pdf

Ford Escape Hybrid (2005-2007):
www.emergencytrainingsolutions.com/downloads/ERGs/Ford%20Escape%20-%20Mercury%20Mariner%20ERG%20(2005-2007.pdf

Ford Escape Hybrid (2008-2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Ford%20Escape%20-%20Mercury%20Mariner%20ERG%20(2008-%20).pdf

Ford Fusion Hybrid (2010):
www.motorcraftservice.com/VDIRS/quickref/2010_Fusion_Hybrid_ERG.pdf

GMC Sierra Hybrid, 1st Generation (2004):
http://www.emergencytrainingsolutions.com/downloads/ERGs/Silverado%20&%20Sierra%20Hybrid%20ERG%20(1st%20Generation).PDF

GMC Sierra Hybrid, 2nd Generation (2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Silverado%20&%20Sierra%20Hybrid%20ERG%20(2nd%20Gen)%20&%20Yukon,%20Tahoe,%20Escalade.pdf

GMC Yukon Hybrid (2008):
www.emergencytrainingsolutions.com/downloads/ERGs/Chevy%20Tahoe%20-%20GMC%20Yukon%20ERG.pdf

www.emergencytrainingsolutions.com/downloads/ERGs/Chevy%20Tahoe%20-%20GMC%20Yukon%20-%20Cadillac%20Escalade%20Quick%20Reference%20Sheet.pdf

Honda Hybrids (All):
techinfo.honda.com/rjanisis/pubs/CI/AXX28935.pdf

Lexus GS450h (2007):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/gs450h.pdf

Lexus HS250h (2010):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/HS250h_erg.pdf

Lexus LS600h L (2008):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/ls600hlhv.pdf

Lexus RX400h (2006-2008):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/rx400h.pdf

Lexus RX450h (2010):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/rx450h_erg.pdf

Mazda Tribute Hybrid (2008):
midsouthrescue.tripod.com/sitebuildercontent/sitebuilderfiles/tributeerg3rdedition.pdf

Mercedes-Benz S400 Hybrid
www.fire.state.mn.us/Response/MercBenzERG.pdf

Mercury Mariner Hybrid (2005-2007):
www.emergencytrainingsolutions.com/downloads/ERGs/Ford%20Escape%20-%20Mercury%20Mariner%20ERG%20(2005-2007.pdf

Mercury Mariner Hybrid (2008-2009):
www.emergencytrainingsolutions.com/downloads/ERGs/Ford%20Escape%20-%20Mercury%20Mariner%20ERG%20(2008-%20).pdf

Mercury Milan Hybrid (2010):
www.motorcraftservice.com/VDIRS/quickref/2010_Fusion_Hybrid_ERG.pdf

Nissan Altima Hybrid (2007):
www.nissanusa.com/pdf/techpubs/altima_hybrid/2007/2007_Altima_Hybrid_FRG.pdf

Nissan Altima Hybrid (2008):
www.nissanusa.com/pdf/techpubs/altima_hybrid/2008/2008_Altima_Hybrid_FRG.pdf

Nissan Altima Hybrid (2009):
www.nissanusa.com/pdf/techpubs/altima_hybrid/2009/2009-Altima-Hybrid-FRG.pdf

Saturn Vue Green Line Hybrid (2007):

www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Vue%20Hybrid%20ERG.pdf
www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Vue%20Hybrid%20Quick%20Reference%20Guide.pdf

Saturn Aura Green Line Hybrid (2007):
www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Aura%20and%20Chevy%20Malibu%20Hybrid%20ERG.pdf
www.emergencytrainingsolutions.com/downloads/ERGs/Saturn%20Aura%20and%20Chevy%20Malibu%20Hybrid%20Quick%20Reference%20Guide.pdf

Toyota Camry HV (2007):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/camryhv.pdf

Toyota Highlander HV, 1st Generation (2006-2007):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/hlanderhv.pdf

Toyota Highlander HV, 2nd Generation (2008):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/hlanderhv2nd.pdf

Toyota Prius, 1st Generation (2001-2003):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/1stprius.pdf

Toyota Prius, 2nd Generation (2004-2009):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/2ndprius.pdf

Toyota Prius, 3rd Generation (2010):
techinfo.toyota.com/techInfoPortal/staticcontent/en/techinfo/html/prelogin/docs/3rdprius.pdf

5. ASSEMBLY OF BEST PRACTICE GUIDANCE FOR EMERGENCY RESPONSE

Every emergency incident to which a fire department responds is unique. Despite the differences, however, there are common characteristics that allow fire service personnel to better understand the tasks that need to be performed and to prepare for their duties. This section provides a review of the common elements of most interest to fire fighters when handling emergencies involving EVs and HEVs.

Identification of Common Themes, Principals, and Core Basics

An emergency incident involving a motor vehicle is not an uncommon occurrence for the fire service. It would not be unusual for a particular fire department to respond to a motor vehicle crash or fire during any given day. This is based on the large number of motor vehicles, of all types, that exist today on public roadways in the United States.

Types of Motor Vehicle Emergencies

The primary emergency scenarios that could be expected by the fire service responding to an emergency involving an EV or HEV are illustrated in Figure 5-1, Key Emergency Scenarios for EVs and HEVs. This figure considers the four basic possibilities of: (1) Extrication/Rescue; (2) Fire; (3) Water Submersion; and (4) Other Scenarios.

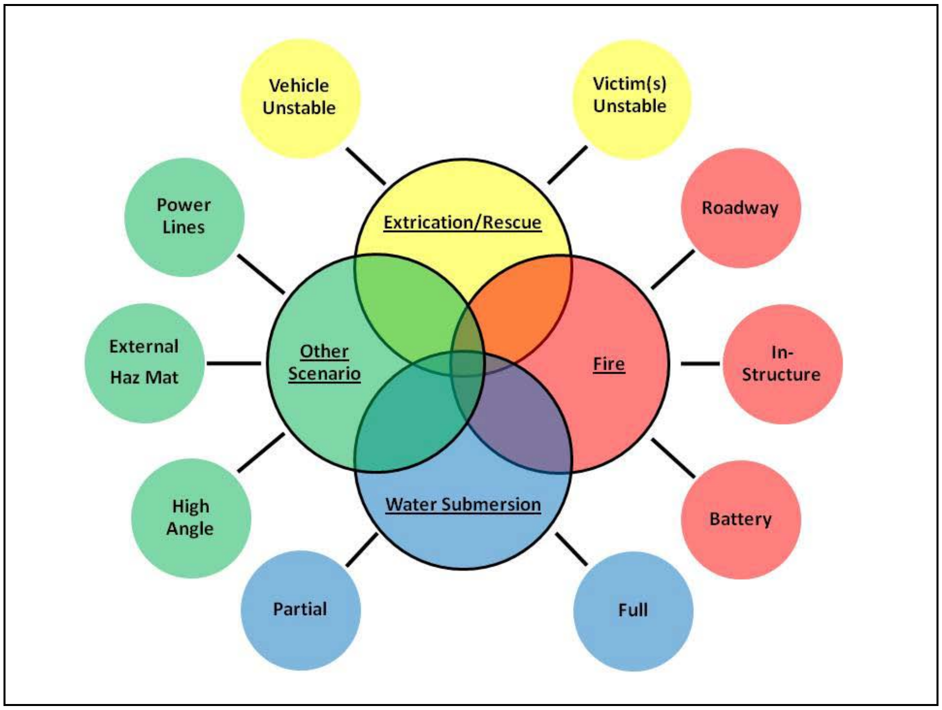


Figure 5-1: Key Emergency Scenarios for EVs and HEVs

The most probable emergency event involving motor vehicles is a motor vehicle accident (MVA). This could be either a collision with another vehicle, with a stationary object (e.g., telephone pole), a collision between multiple vehicles, or any combination of these. Often an MVA will include victims with injuries requiring prompt medical attention. In some situations the victims may be trapped and require extrication. Vehicle rescue and extrication is a specialized function performed by the fire service, and it is a task in which an EV or HEV may present additional hazards to the emergency responders (i.e., electrical shock) when they are cutting and removing portions of the damaged vehicle.

Another possible emergency incident for responding fire fighters is a vehicle fire. This may be the result of an MVA, or it may be a fire occurring independent of any collision or crash, as in the case of a parked vehicle. A factor of paramount concern to fire fighters is if the burning vehicle is in an open area with no exposures (i.e., roadway or highway), or if it is within or near a structure with serious exposure concerns (e.g., within a residential garage). Another issue of importance for EVs or HEVs as compared to a conventional motor vehicle, is if the high voltage battery sustains direct fire and heat damage and how this fire is controlled and mitigated.

Other emergency scenarios include the vehicle being partially or fully submerged in water, with or without entrapment. Other scenarios include additional challenging special hazards that could occur with any motor vehicle, such as the vehicle draped by downed power lines, an external hazardous materials incident exposing the vehicle, or a high angle rescue such as on the edge of a bridge or cliff. These special situations can be especially problematic when they occur with entrapment and require extrication.

Hazards Unique to EVs and HEVs

Electric vehicles and hybrid electric vehicles are generally very similar in appearance to conventional vehicles, and can sometimes not be easily distinguished from them. Arguably the greatest single challenge for the emergency responder to an event involving an EV or HEV is *assessment* or *size-up*, which includes adequately identifying the vehicle and the hazards it contains.

Knowing that the vehicle is an EV or HEV is critical to handling the event in a reasonably safe manner. Identifying an EV or an HEV is not necessarily straightforward. There are direct means such as recognition of the specific model, or in some cases the "*hybrid*" logo is stated on the vehicle's exterior. Indirect means include a review of the instrumentation panel that reveals the vehicle's electrical propulsion system, or examining under the hood or trunk. Conveniently, some models have very prominent indications that they are an HEV, but on others this is not obvious. Figure 5-2 illustrates an example of an EV dashboard and driver's control console.

Figure 5-2: EV Interior and Control Console
(Photo courtesy of NREL Photographic Information Exchange)

The same hazards in a conventional vehicle also apply to an EV and HEV, including those mentioned earlier in Figure 3-1, Hazardous Materials Normally Found in Conventional-Fueled Vehicles. Some of these are independent of the type of propulsion system used, such as compressed gas or explosive cartridges used for air bags.

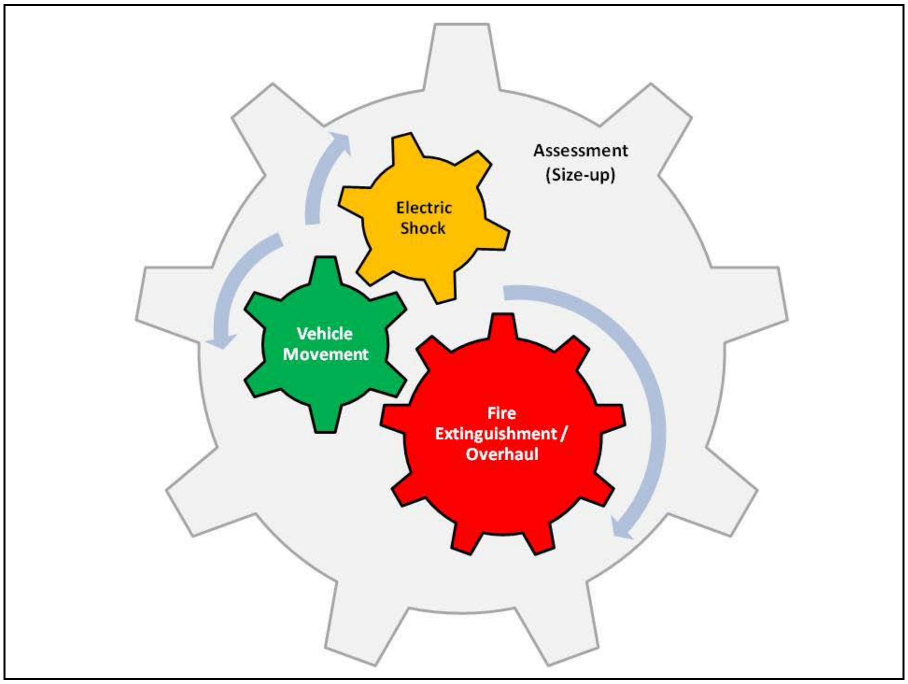


Figure 5-3: Additional Fire Service Hazards/Concerns for EVs and HEVs

Likewise, the hazards with EVs and HEVs are very similar to the hazards inherent with conventional motor vehicles, with additional points of attention and awareness mostly focused on the electric shock hazard, vehicle movement, and fire extinguishment/overhaul, with the need in all cases to achieve proper assessment and size-up. These are illustrated in Figure 5-3, Additional Fire Service Hazards/Concerns for EVs and HEVs, and explained in further detail in the following sections. The additional hazards/concerns in Figure 5-3 and the common hazards/concerns expressed earlier, which are common in all of today's internal combustion engine motor vehicles (from Figure 3-1) are collectively summarized in Table 5-1.

Table 5-1: Fire Service Hazards/Concerns for EVs and HEVs

Additional Hazards/Concerns for EVs and HEVs (see Figure 4-3)	
Assessment (Size-Up)	**Electric Shock**
	Vehicle Movement
	Fire Extinguishment/Overhaul
Examples of Hazardous Materials Common in All ICE Motor Vehicles (see Figure 3-1)	
Air Bag System (explosive initiators, non-flammable compressed gas)	
Air Conditioner Refrigerant (non-flammable compressed gas)	
Batteries (corrosive liquids)	
Brake Accumulators (high pressure gas)	
High Intensity Discharge Headlamps (electrical discharge)	
Gasoline/Fuel (flammable liquid)	
Seat-Belt Pretensioners (explosive initiators, non-flammable compressed gas)	
Shocks & Struts (flammable fluid and compressed gas)	

Fire fighting professionals have expressed the opinion in the published literature that the specific hazards of EVs and HEVs are at times overemphasized, and that they can be readily managed with adequate preparation and common sense. Although different, they are not extraordinary in terms of their challenges to control and mitigate as compared to conventionally powered vehicles. As such, the basic approach used with conventional vehicles is applicable with the appropriate common sense modifications.[143]

An area of concern that should not be overlooked is the need to assure that the EV/HEV emergency scene is adequately stabilized for post-event activities. This includes fire investigations, as well as tow and salvage operations. Hazards such as live electrical components in a damaged EV or HEV should not be ignored prior to the removal and disposal of the damaged vehicle. After a vehicle has been involved in a collision, fire, submersion, or other damaging event, safety systems may have been compromised. It is important that fire investigators, tow operators and others are aware of the potential hazards during post-emergency-event operations. An example of these concerns is provided by the following excerpt from the 2008 edition of NFPA 921, *Guide for Fire and Explosion Investigations*.[144]

> **25.14.1 Hybrid Vehicle Investigation Safety.** As a safety precaution, the investigator should approach the hybrid vehicle as though the high voltage system is energized. Before inspecting a hybrid vehicle the investigator should be familiar with the high voltage system. Most hybrid vehicles will have a manual disconnect means to isolate high voltage to the battery pack.

Investigators should ensure that the disconnect is in the isolation position before beginning any physical inspection. As an additional precaution, a voltmeter should be used to check whether high voltage is present on any suspect wiring or component.
WARNING: *Because the high voltage battery potential could range up to 600 volts, opening the battery pack could be extremely hazardous and should not be attempted by untrained personnel.*

Extrication & Rescue

Extrication of trapped victims from a damaged motor vehicle is among the most significantly challenging tasks faced by fire fighters during an emergency event. Often the victims are in dire need of medical treatment and rapid intervention is essential, and meanwhile the risks of the situation may be further complicated with a cadre of additional challenges such as vehicle fire, downed power lines, or an external hazardous materials exposure.

Preparation and training for vehicle extrication is paramount to achieving an efficient operation that takes reasonable precautions for the emergency responders and victims alike. While every event involving extrication and rescue is unique, certain approaches used by the fire service provide clear direction to emergency personnel on how to handle the event.

A team-based approach proposed by Wimer is based on coordinating resources into four sub-units that focus on the following: stabilization team; power-down team; extrication team; and the decontamination team.[146] Each of these resource units has specific duties and responsibilities, and they interact and support each other using defined brother/sister relationships. This concept is illustrated in Figure 5-4, Example of Approach to Extrication & Rescue.

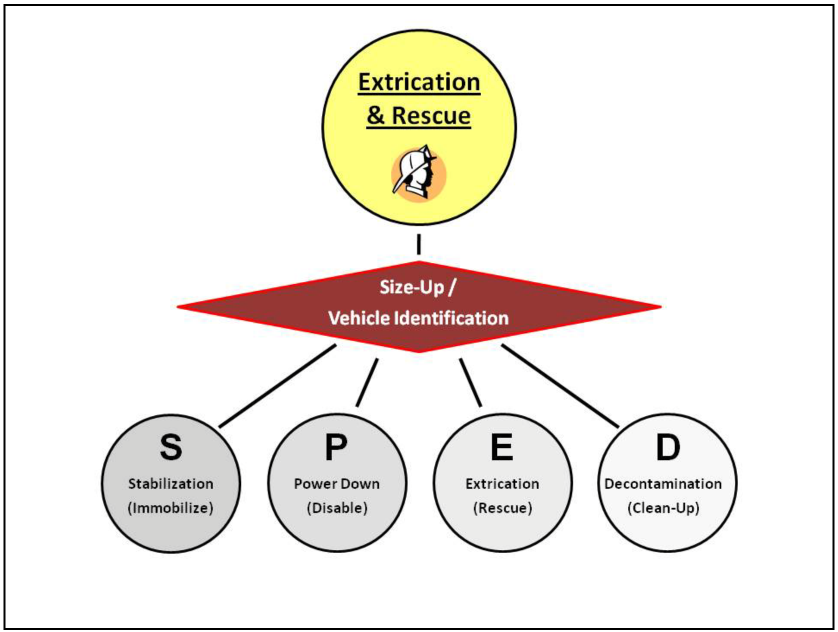


Figure 5-4: Example of Approach to Extrication & Rescue[148]

In terms of vehicle extrication, perhaps the most significant difference between a conventional vehicle and an EV or HEV is the high voltage electrical system. EVs and HEVs typically include high voltage batteries, and the presence of high voltage components creates a possible electrocution hazard (between 36 and 600 volts of electricity) to emergency personnel, especially before they realize the vehicle is a hybrid model.[147]

The cabling for these high voltage systems were voluntarily colored bright orange by auto manufacturers for easy and consistent identification. In certain recent models blue and yellow color coded cables have appeared that also present a dangerous shock hazard, despite not being specifically considered as high voltage. Further, the high voltage cabling in vehicle designs is often shielded in protective conduit channels making it hard to visually locate.

While the high voltage in electric and hybrid electric vehicles understandably raises concerns among fire fighters that demand a higher degree of caution, it also leads to certain misconceptions that deserve to be addressed. For example, electrocution is not a realistic hazard from simply touching the exterior of a crashed EV or HEV.[149] This should be no different than a conventional motor vehicle, since the high voltage system is fully isolated from the vehicle chassis/body. However, the one obvious exception for an exterior electrocution hazard, and which would apply with any vehicle, is a crash situation involving an exterior electrical power source such as when downed power lines are draped over the crashed vehicle.

An EV or HEV also has a low voltage electrical system (e.g., 12 VDC) for the lights, horns, and other accessories similar to conventional vehicles. Unlike the high voltage system, this is typically grounded through the chassis/body and presents no realistic electrical shock hazard to emergency responders. The high voltage systems in EVs and HEVs are typically equipped with multiple automatic sensory device contact-relays that fail in an *open* position and stop the high voltage flow, including the activation of the airbags and related emergency collision systems.

These normally open relays for the high voltage system are moved into the closed position when energized by low voltage electrical power. Therefore, interrupting the low voltage electrical power source (i.e., removing the low voltage power cable similar to a conventional vehicle) effectively shuts down the flow of high voltage electricity. However, it is very important to be aware that it takes some fixed amount of time (e.g., up to 10 minutes depending on the manufacturer) for power in the high voltage system to fully dissipate after it has been isolated. Figure 5-5 illustrates side-by-side high voltage and low voltage batteries in an NEV.

An additional critical safety caution to emergency responders: After removing low voltage power to the normally open relays, the high voltage batteries are still fully energized as is all high voltage wiring (normally orange colored) still directly connected to the high voltage batteries. Thus the high-voltage batteries and cabling should always be treated as a serious electrocution hazard and never cut or compromised in any manner. It is typical for a set of normally open relays to be located at the high voltage battery connection, and in such designs this aids the emergency responder by fully isolating the high voltage battery from its associated cabling following the respective high voltage energy dissipation time.

Figure 5-5: NEV High Voltage and Low Voltage Battery Modules
(Photo courtesy of NREL Photographic Information Exchange)

An EV or HEV submerged in water also raises questions about electrocution from touching the vehicle. Again, this is not a realistic hazard and should be no different than a conventional motor vehicle and any electrical leakage will be undetectable to the touch. The same basic approach used by emergency responders for conventional vehicles should be implemented, such as stabilizing and removing the vehicle from the water if possible.

Different methods exist for disabling an EV or HEV during a vehicle extrication and rescue. Aside from chocking the wheels and other standardized methods for stabilizing any vehicle, it is more of a challenge to fully disable an EV or HEV because of their ability to function silently. It is imperative for the emergency responder to assure that they have disabled the vehicle's ability to operate.

Some manufacturers suggest that first responders shut down a hybrid vehicle by putting it in park, turning off the internal combustion engine, and removing the ignition key. Certain models may not have an ignition key but instead use a push button start when a key fob is within range (i.e., 10 feet), and these require additional caution to assure shutdown. Additional obvious tactics include disconnecting the low voltage battery system if accessible, similar to that of a conventional vehicle,that also disables the high voltage system on an EV or HEV.

The following are some general considerations for emergency responders addressing an event involving these vehicles, as provided by the U.S. Fire Administration in a recent Info-Gram:[150]

- Always assume the vehicle is powered-up despite no engine noises.
- Put vehicle in park, turn ignition off, and remove key to disable the high voltage system.
- Never touch, cut, or open any orange cable or components protected by orange shields.
- Remain a safe distance from vehicle if it is on fire.
- Consider the electrical system unsafe for at least a full 10 minutes after ignition shut-down.
- Contact local auto dealerships for more information about their hybrid vehicles.

The primary elements included in the procedures for handling extrication and rescue of victims from any motor vehicle will vary. However, the basic elements are included in Figure 5-6 Summary of Basic Elements of Vehicle Rescue from NFPA 1670, as taken from Chapter 8 of NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*.[151]

8.1* General Requirements.

Organizations operating at vehicle and machinery search and rescue incidents shall meet the requirements specified in Chapter 4.

(Note: **A.8.1** It is the intent of this provision that the AHJ, as part of the hazard identification and risk assessment, identify the types of vehicles and machinery within its response area. These types can include, but are not limited to, cars, trucks, buses, trains, mass transit systems, aircraft, watercraft, agriculture implements, industrial/construction machinery, and elevators/escalators. The AHJ should develop procedures and provide training to personnel that is commensurate with the potential for search and rescue situations involving the above-mentioned vehicles and machinery.)

8.2 Awareness Level.

8.2.1 Organizations operating at the awareness level for vehicle and machinery emergencies shall meet the requirements specified in Section 8.2.

8.2.2 All members of the organization shall meet the requirements specified in Chapter 4 of NFPA 472, *Standard for Professional Competence of Responders to Hazardous Materials Incidents*.

8.2.3 Organizations operating at the awareness level for vehicle and machinery emergencies shall implement procedures for the following:

(1) Recognizing the need for a vehicle and machinery search and rescue

(2)* Identifying the resources necessary to conduct operations

(Note: **A.8.2.3(2)** See A.4.2.5.)

(3)* Initiating the emergency response system for vehicle and machinery search and rescue incidents

(Note: **A.8.2.3(3)** The emergency response system includes, but is not limited to, operations- and technician-level organizations capable of responding to various types of search and rescue incidents, as well as local, state, and national resources.)

(4)* Initiating site control and scene management

(Note: **A.8.2.3(4)** These procedures should include the process of achieving and maintaining control of the site and the perimeter. They might include management of all civilian and nonemergency personnel and establishment of operational zones and site security.)

(5)* Recognizing general hazards associated with vehicle and machinery search and rescue incidents

(Note: **A.8.2.3(5)** General hazards associated with operations at vehicle and machinery search and rescue incidents can present the AHJ with uniquely challenging situations. The AHJ should consider the following potential hazards when providing training to its members.

(1) Utilities. Control of the utilities in and around a vehicle or machinery search and rescue incident is critical to ensure the safety of responding personnel and victims. The AHJ should provide its members with training in the control of these services to provide a safe environment in which to operate and to ensure the safety of victims. The following utilities should be considered when providing training:

(a) Electrical services (primary and secondary)
(b) Gas, propane, fuel oil, or other alternative energy sources (primary systems)
(c) Water
(d) Sanitary systems
(e) Communications
(f) Secondary service systems (such as compressed, medical, or industrial gases)

(2) Hazardous Materials. Vehicle and machinery rescue incidents might include various materials that, when released during an incident, could pose a hazard to victims and responders. The AHJ should provide members with training in the recognition of potential hazardous material releases, the determination of an existing hazard, and the methods used to contain, confine, or divert hazardous materials to conduct operations safely and effectively.

(3) Personal Hazards. At the site of any vehicle and machinery search and rescue incident, there are many dangers that pose personal injury hazards to the responders. The AHJ should train members to recognize the personal hazards they encounter and to use the methods needed to mitigate these hazards to help ensure their safety. Every member should be made aware of hazards such as trips, falls, blows, cuts, abrasions, punctures, impalement, and so forth.

(4) Movement of Vehicle(s) and Machinery. Uncontrolled movement of vehicle(s) and machinery components can cause extremely hazardous and potentially fatal situations. Responding personnel should be familiar with and trained in techniques for stabilizing and removing the potential for movement of vehicle(s) and machinery components.

(5) Release of High-Pressure Systems. Vehicles and machinery often include high-pressure systems (e.g., hydraulic, pneumatic) that can fail without warning. Such failure can cause extremely hazardous conditions, injury, and death of victims and responders. The AHJ should provide members with training in the recognition of potential high-pressure system hazards, the determination of an existing hazard, and the methods used to contain, confine, or divert such hazards to conduct operations safely and effectively.

(6) Other Hazards. There are numerous other hazards associated with vehicle and machinery search and rescue incidents. The AHJ should make every effort to identify the hazards that might be encountered within the jurisdiction and should provide members with training and awareness of these other hazards to allow them to perform search and rescue operations safely and effectively.)

(6) Initiating traffic control

8.3 Operations Level.

8.3.1 Organizations operating at the operations level for vehicle and machinery emergencies shall meet the requirements specified in Sections 8.2 and 8.3.

8.3.2 All members of the organization shall meet the requirements of Chapter 5 of NFPA 472, Standard for Professional Competence of Responders to Hazardous Materials Incidents.

8.3.3 The organization shall have members capable of recognizing hazards, using equipment, and implementing techniques necessary to operate safely and effectively at incidents involving persons injured or entrapped in a vehicle or machinery.

8.3.4 Organizations operating at the operations level for vehicle and machinery emergencies shall develop and implement procedures for the following:

(1)* Sizing up existing and potential conditions at vehicle and machinery search and rescue incidents

(Note: **A.8.3.4(1)** The size-up should include, but not be limited to, the initial and continuous evaluation of the following:

(1) Scope and magnitude of the incident
(2) Risk/benefit analysis (body recovery versus rescue)
(3) Number and size of vehicles or machines affected
(4) Integrity and stability of vehicles or machines affected
(5) Number of known or potential victims
(6) Access to the scene
(7) Hazards such as disrupted or exposed utilities, standing or flowing water, mechanical hazards, hazardous materials, electrical hazards, and explosives
(8) Exposure to traffic
(9) Environmental factors
(10) Available versus necessary resources

(2) Identifying probable victim locations and survivability

(3)* Making the search and rescue area safe, including the stabilization and isolation (e.g., lockout/tagout) of all vehicles or machinery involved

(Note: **A.8.3.4(3)** The search and rescue area is that area immediately surrounding [within a 6.10 m (20 ft), or so, radius of] the vehicle or machinery. Making the search and rescue area safe includes, but is not limited to, the following actions; however, specific actions should be based on the vehicle or machinery type and specific situation:

(1) Establishing operational zones (i.e., hot, warm, cold) and site security
(2) Utilizing specific techniques and tools (including cribbing, chocks, and wedges) to stabilize the vehicle
(3) Utilizing specific techniques and tools (i.e., lockout and tagout) to isolate the involved equipment
(4) Making the search and rescue area (i.e., hot zone) safe for entry
(5) Safely undertaking disentanglement and extrication operations using hand tools
(6) Ventilating the search and rescue area and monitoring its atmosphere when necessary
(7) Supporting any unbroken utilities
(8) Providing protective equipment for any victims, if possible, when necessary
(9) Prohibiting entry into an unsafe vehicle or machinery search and rescue area
(10) Preventing the touching or operating of equipment or machinery involved until its safety has been established)

(4) Identifying, containing, and stopping fuel release
(5) Protecting a victim during extrication or disentanglement
(6) The packaging of a victim prior to extrication or disentanglement
(7) Accessing victims trapped in a vehicle or machinery
(8)* Performing extrication and disentanglement operations involving packaging, treating, and removing victims trapped in vehicles or machinery through the use of hand and power tools

(Note: **A.8.3.4(8)** To ensure a safe disentanglement or extrication operation, the AHJ should provide training on the following topics:

(1) Types of passenger restraint systems
(2) Frame and construction features of vehicles

(3) Types of suspension systems in vehicles
(4) Types and classification of impacts
(5) Categories of mechanical injury
(6) Various stabilization techniques
(7) Center of gravity and its relationship to rollover
(8) Use of cribbing and chocks
(9) Building a crib box
(10) Types and examples of levers for mechanical advantage
(11) Proper and effective use of hand tools including a hammer, pry bar, hacksaw, glass punch, Halligan, knife or belt cutter, cable cutter, and come-along
(12) Disentanglement through primary access points
(13) Patient packaging prior to removal from a vehicle or machine
(14) Protection of the victim during extrication or disentanglement operations
(15) Proper and effective use of power tools such as hydraulic, pneumatic, and electrical spreading, cutting, lifting, and ram-type tools)

(9)* Mitigating and managing general and specific hazards (i.e., fires and explosions) associated with vehicle and machinery search and rescue incidents

(Note: **A.8.3.4(9)** These procedures refer to the mitigation and management of the hazards identified in A.8.2.3(5).)

(10) Procuring and utilizing the resources necessary to conduct vehicle and machinery search and rescue operations

(11) Maintaining control of traffic at the scene of vehicle and machinery search and rescue incidents

8.4 Technician Level.

8.4.1 Organizations operating at the technician level for vehicle and machinery emergencies shall meet the requirements specified in this chapter.

8.4.2 Organizations operating at the technician level for vehicle and machinery emergencies shall develop and implement procedures for the following:

(1) Evaluating existing and potential conditions at vehicle and machinery search and rescue incidents

(2)* Performing extrication and disentanglement operations involving packaging, treating, and removing victims injured or trapped in large, heavy vehicles or machinery

(Note: **A.8.4.2(2)** To ensure that disentanglement or extrication from large, heavy vehicles or machines is performed safely, the AHJ should provide training on the following topics:
(1) Frame and construction features of heavy, large vehicles and machinery
(2) Use and components of a search and rescue chain assembly
(3) Pneumatic high-, medium-, and low-pressure lifting bags
(4) Use, care, and maintenance of wire rope and its associated equipment
(5) Large and heavy object weight estimation
(6) Steps necessary to lift or move large objects
(7) Use of cribbing and chocks with large and heavy objects
(8) Use of commercial heavy wreckers and recovery services to assist at incidents involving large transportation vehicles
(9) Use, care, and maintenance of both manual and power winches
(10) Types and examples of lifting devices that use mechanical advantage principles
(11) Proper and effective use of power tools including hydraulic, pneumatic, and electrical spreading, cutting, lifting, and ram-type tools
(12) Disentanglement through both primary and secondary access points through the use of

available power tools
(13) Protection of the victim during this type of extrication or disentanglement operation
(14) Lockout/tagout of machinery
(15) Identification and use of various sling configurations)
(3)* The advanced stabilization of unusual vehicle and machinery search and rescue situations
(Note: **A.8.4.2(3)** "Unusual" situations include, but are not limited to, extrication or disentanglement operations at incidents involving cars on their tops, cars on their sides, and cars on top of other cars, trucks, and large commercial vehicles. "Advanced stabilization" includes techniques using chains, cables, jack devices, and cribbing or shoring to stabilize vehicles of any size.)
(4)* Using all specialized search and rescue equipment immediately available and in use by the organization
(Note: **A.8.4.2(4)** Power tools (e.g., air bags, hydraulic spreaders and rams, hand tools, and other power tools) and training necessary to remove, cut, and move components displaced at a vehicle or machinery search and rescue incident should be provided. "Specialized rescue equipment" can include, but is not limited to, hydraulic, pneumatic, and electrical spreading, cutting, lifting, and ram-type tools immediately available and in use by the organization.)

Figure 5-6: Summary of Basic Elements of Vehicle Rescue from NFPA 1670[152]

Fire Extinguishment and Overhaul

A fire involving an EV or HEV should generally be approached in the same manner as a conventional motor vehicle, although several additional factors should be considered. One approach indicating the basic steps that should be taken into account for extinguishing a fire involving any motor vehicle (including an EV or HEV) are illustrated in Figure 5-7, Example of Approach to Vehicle Fire Extinguishment.

As with vehicle extrication and rescue, a vehicle fire also involves important steps to stabilize and disable the vehicle. Although it may appear to be "off", the silent operational characteristics present a realistic hazard for fire fighters attacking the vehicle fire. It is imperative for the emergency responder to assure that they have disabled the vehicles ability to operate as much as possible.[153]

Vehicular high voltage battery packs often use metal housings, but those that include plastic shielding and/or casing components create challenging fire control and suppression situations if they become directly involved in a fire. Extinguishing a fire involving vehicle batteries depends on multiple factors such as type of battery, extent of fire involvement, battery configuration, physical (collision) damage to battery unit, etc. If water is used, copious amounts are normally required and this might be impractical if the vehicle and battery unit is not accessible and runoff is a concern. Various emergency response guides from vehicle manufacturers generally recommend a defensive approach to controlling a high voltage battery fire (i.e., letting it burn and consume itself) if there are no exposures to the heat and/or products of combustion. Figure 5-8 illustrates a NiMH EV battery module that has the cover cut away for purposes of demonstration.

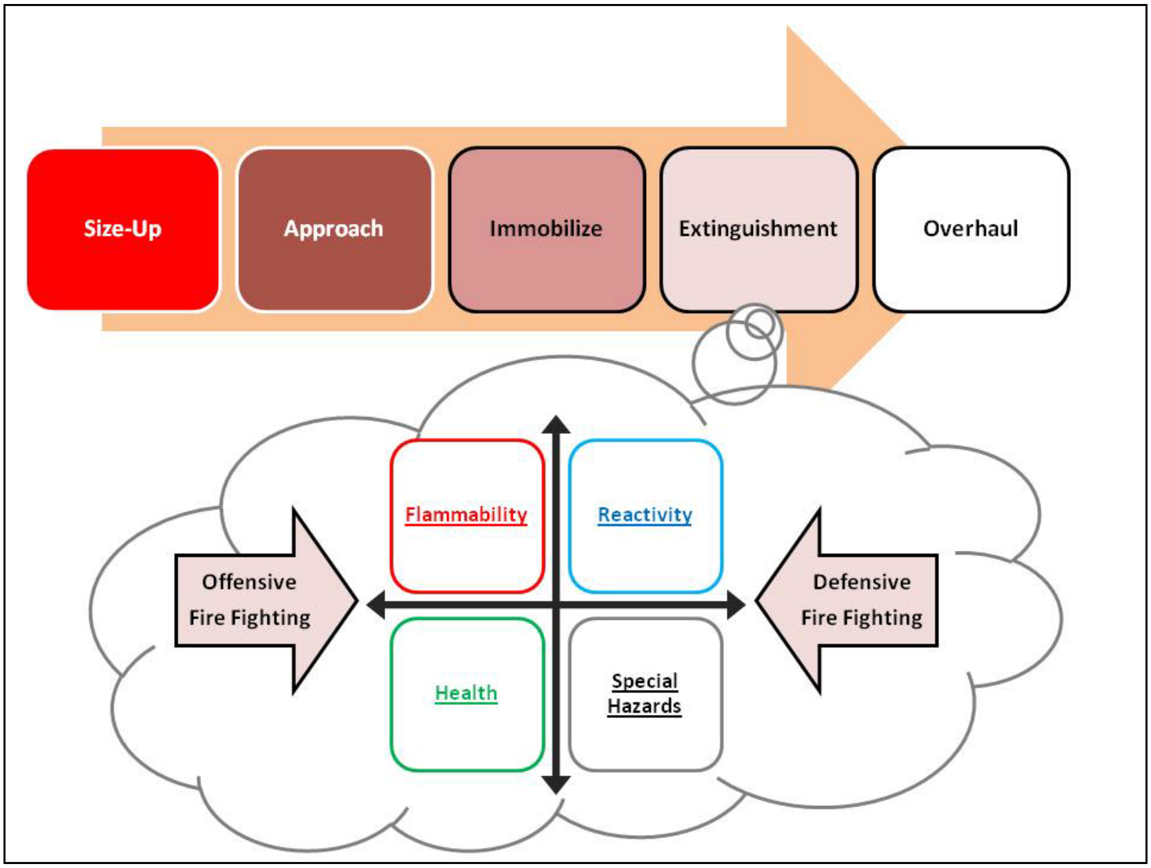


Figure 5-7: Example of Approach to Vehicle Fire Extinguishment

With or without a fire, the design of today's high voltage battery packs makes them unlikely to be compromised to the point of leakage. If this does occur as a result of a severe crash of an EV or HEV, it is generally not necessary to call for a hazardous materials response. The nickel metal hydride batteries used as high voltage batteries in almost all of today's EVs and HEVs do not contain enough fluid electrolytes in the individual modules. These modules are effectively dry batteries, since the fluids are absorbed within the fiber material between the metal plates. Spills can normally be handled with an absorbent that is suitable for a strong base liquid. As new battery designs and technological improvements are introduced in the coming years, this basic approach will need to be re-evaluated.

When a battery system is involved in fire, the type of batteries involved and multiple design factors (e.g., dry versus wet batteries, size of individual cells, etc.) can make a significant difference in how fire extinguishment is implemented. For example, the *Emergency Response Guidebook* for the U.S. Department of Transportation advises that for small lithium ion battery fires (i.e., vehicles) fire extinguishment can be attempted using dry chemical, CO_2, water spray, or regular foam. For large fires, the guidebook's recommended extinguishing method is water spray, fog, or regular foam, and it also suggests moving containers/components away from the fire area if it can be done without risk.[154] The variety of different battery types and configurations complicates the tactics of battery fire extinguishment, and suggests multiple approaches beyond a single straight-forward recommended fire extinguishing procedure.

Figure 5-8: Cut-Away Demonstration Version of a NiMH EV Battery Module
(Photo courtesy of NREL Photographic Information Exchange)

Previous large-scale fire events at battery manufacturing and recycling facilities have proven to be extremely challenging, such as an August 2008 battery factory fire in Karlstein, Germany, and a November 2009 fire that destroyed a manufacturing facility in Trail, British Columbia.[155,156] However, these large-scale events are not readily comparable to the small battery systems and configurations found in motor vehicles. These systems are inherently limited in quantity and do not present the same fire extinguishment challenges. While certain fire characteristics may be comparable, such as concern for limited products of combustion, evaluating these large-scale facility events as representative of electric vehicle fires is usually not a realistic comparison.

As general guidance on fire fighter protection, depending on the type of system, battery fires may involve spilled electrolyte and full protective clothing and respiratory protection is imperative in such incidents, as well as special care and maintenance during cleanup. Dry chemical, CO_2, and foam are often the preferred methods for extinguishing a fire involving batteries, and water is often not the first extinguishing agent of choice.[157] However, the types and designs of batteries varies considerably and directly impacts fire fighting methods. Further research is needed to clarify proper fire extinguishing methods for current and developing vehicle batteries.

Another important consideration with an EV or HEV fire is that the automatic built-in protection measures to prevent electrocution from the high voltage system may be compromised. For example, the normally open relays for the high voltage system could possibly fail in a closed position if exposed to heat and if they sustain damage. Further, short circuits to the chassis/body may become possible with the energy still contained in the high voltage battery or any of the high voltage wiring still connected to the battery.

Final disposal of a damaged EV or HEV is more challenging than what is normally required for a conventional motor vehicle. During an emergency situation, whether it is a rescue scenario or a vehicle fire, fire service personnel are advised to always treat an EV or HEV high voltage system as if it is “on” or “live.” But after the emergency situation is mitigated and the scene secured, at what point do we really consider the vehicle “safe” for disposal? For a traditional gasoline-powered motor vehicle, a wrecked or burned out car is more readily considered as an inert and relatively safe object, but EVs/HEVs raise the additional question about safe disposal protocols.

Charging Stations

Fires involving vehicles do not always occur on the open roadway. On occasion they occur in a vehicle located near or within a commercial or residential parking structure. Figure 5-9 shows an EV fleet charging station underneath a partial structure constructed primarily of photovoltaic solar panels. These fires tend to be particularly challenging due to the obvious exposure hazard of the host structure. While recommendations for certain types of battery fires are to allow them to burn themselves out, this recommendation becomes more challenging when the vehicle is located within a parking structure.

Figure 5-9: An EV Fleet Charging Station
(Photo courtesy of NREL Photographic Information Exchange)

Further complicating an indoor fire are the charging stations that are expected to become common for these indoor parking facilities. Outdoor charging stations in open weather-resistant settings would involve limited exposure concerns during a fire event, although the associated electrical hazards would not be diminished. An example is shown in Figure 5-10 of an outdoor solar-powered EV charging station. Special fire fighting procedures will need to be considered depending on the technology and materials used for these charging stations and will likely need to be handled similarly to fires involving energized electrical equipment. Charging stations that utilize photovoltaic solar panels provide the added challenge to emergency responders of always generating electricity when exposed to sunlight.

Figure 5-10: Outdoor Solar Power EV Charging Station
(Photo courtesy of NREL Photographic Information Exchange)

A key strategy in such fires is to isolate the power supply and de-energize the charging equipment. Importantly, this may become difficult to implement if a vehicle is on fire and is plugged into the charging station, since the vehicle batteries themselves will be the power source back into the building. The ability to control the backfeeding of electrical energy from the vehicle back to the charging station (and the building's electrical system) is a technical issue actively being addressed in the code requirements for charging station installations. An example of an EV charging station is shown in Figure 5-11.

Figure 5-11: Electric Vehicle Charging Station
(Photo courtesy of State Farm Vehicle Research Facility)

A concept for quickly identifying possible hazards involving unique equipment within a structure, such as an electric vehicle charging station, is the development and implementation of an identification system providing critical information for emergency responders. This approach already exists in a general sense, such as with the "Fire Fighter Safety Building Marking System" (FFSBMS) described in Annex Q of NFPA 1, *Fire Code*, 2009 edition.[158] The FFSBMS provides a fire fighter safety building marking system with basic building information for fire fighters responding to the building or structure. Figure 5-12 illustrates a sample sign for the FFSBMS, which reserves the center of the Maltese cross for indication of special hazards, This system is an example of an approach to identify special or unusual emergency response concerns, such a residential structure with an EV charging station using high voltage for rapid recharging.

Figure 5-12: Sample Sign for Fire Fighter Safety Building Marking System[159]

Target Application Workshop

Electric drive and hybrid electric vehicles are starting to see widespread popularity, and they are one of the new challenges facing the U.S. fire service. Some fire service organizations are in the process of developing recommended emergency response procedures and best practices on a local or regional basis; in other jurisdictions, basic information on the hazard and appropriate response is lacking or not readily available.

One of the ways this project addresses these concerns is to collect and analyze all applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to electric drive and hybrid electric vehicles. To assist in accomplishing this task, an interactive one-day workshop was held, "Fire Service Workshop on Electric Drive and Hybrid Electric Vehicles." This workshop involved experts on fire service and other subject matter and took place on Tuesday, 16 March 2010 at the Next Energy facility in Detroit Michigan. The workshop was attended by approximately 2½ dozen experts knowledgeable on fire service issues relating to electric and hybrid electric vehicles, and a summary of workshop attendance is included in Annex G, "Attendees at Fire Service Workshop on Electric Drive and Hybrid Electric Vehicles".

The goal of the workshop was to identify, review, and assemble best practice information for tactical and strategic decision making by fire fighters and fireground incident commanders, to assist in their decision-making process when responding to fire and/or rescue emergency events involving electric drive and hybrid electric vehicles, including within structures (e.g., residential garages). This goal was accomplished using an interactive approach involving subject-matter experts that focused on the following workshop objectives:

- Collectively review the available baseline information (provided to participants prior to the workshop);
- Identify the fundamental principles and key details involving fire/rescue tactics and strategy, and provide a summary of core basics; and
- Address and clarify related issues such as training needs, areas needing further research, revisions to codes/standards, and other topics applicable to the overall workshop goal.

Final Evaluation of Best Practice Guidance

The workshop included a detailed review of the baseline information represented by the balance of content contained within this report. Three working groups were established among the attendees who, as part of the workshop, separately addressed a set of ten similar questions.

These ten questions were grouped into three sets according to: (1) current practice; (2) future trends; and (3) other issues. Each working group reported their individual results to the entire workshop to support a collective discussion among all attendees. Based on the collective discussion of all attendees, the responses from each working group were subsequently consolidated and harmonized into a single set of responses for each question. This consolidated response is summarized in Figure 5-13, Workshop Working Group Summary.

FIRE SERVICE WORKSHOP ON ELECTRIC DRIVE & HYBRID ELECTRIC VEHICLES

Detroit, MI
16 March 2010

Working Group Summary

The following set of ten questions was addressed independently by three separate working groups at this workshop. This consolidated "Working Group Summary" provides their collective responses, and for each question is provided in a non-prioritized, harmonized summary-format.

I. CURRENT PRACTICE

A. In terms of prioritized hazards, how should this topic be scoped?

1. Vehicle Types
    - 1.1. Geographic Scope: Include only vehicles available in U.S. market
    - 1.2. Production Scope: Include only new or used vehicles available in U.S. market
    - 1.3. Exclude non-OEM vehicles and after-market conversions
2. Vehicle Hazards
    - 2.1. Focus on hazards unique to EVs and HEVs

        - 2.1.1.Electric Shock
        - 2.1.2.Vehicle Movement
        - 2.1.3.Fire Extinguishment
        - 2.1.4.Other: Post-fire stabilization, decontamination, etc.
    - 2.2. Address hazards also common to all vehicles (e.g., HIDs, etc.)
- 3. Incident Types
    - 3.1. Include: collision, fire, submersion in water
    - 3.2. Do not exclude other possible events: hazmat exposure, external power lines, etc.
    - 3.3. Event location
        - 3.3.1.Without exposures (e.g., open roadway, etc.)
        - 3.3.2.With external exposures (e.g., at charging station in a garage, etc.)
- 4. Emergency Responder Characteristics
    - 4.1. Include: Fire service, EMS, and law enforcement
    - 4.2. Consider others involved with emergencies (e.g., dispatchers, tow operators, etc.)
    - 4.3. Maintain clarification between safety to public vs. safety to emergency responders
- 5. Other
    - 5.1. Address applicable related hazards (e.g., environmental impact)
    - 5.2. Provide deliverables that can be readily implemented and universally applied

B. What are the prioritized core basics for emergency responders to address the topic?

- 1. Scene Assessment
    - 1.1. Establish vehicle identification
    - 1.2. Identify other critical factors (e.g., patient condition, etc.)
    - 1.3. Promote a VSDS (Vehicle Safety Data Sheet) type approach
    - 1.4. Enable accurate reliable dispatch information (e.g., OnStar)
- 2. Early Vehicle Stabilization
    - 2.1. Immobilize, stabilize, and disable
        - 2.1.1.External to vehicle (e.g., wheel chocks, etc.)
        - 2.1.2.Power down procedure (e.g., disconnect switch, 12 V battery disconnect)
    - 2.2. Keyless ignitions
- 3. Tactical Issues
    - 3.1. Clarify fire extinguishment procedure for batteries and high voltage components
    - 3.2. Address post-event stabilization

C. What is specifically needed for operational procedures and training materials?

- 1. Operational Materials
    - 1.1. Include basic overview information on vehicles and vehicle technology
    - 1.2. Provide universal and readily accessiable emergency responder guides (similar to ERG from PHMSA)
    - 1.3. Standardize Certain Vehicle Characteristics
        - 1.3.1.Formats for vehicle emergency response guides
        - 1.3.2.Electrical cable coloring
        - 1.3.3.Emergency shut-off locations
        - 1.3.4.Vehicle identification and labeling
    - 1.4. Critical Operational Concerns
        - 1.4.1.Vehicle identification and labeling
        - 1.4.2.Details of high voltage system
        - 1.4.3.Process for immobilization, stabilization, and disabling

        - 1.4.4.Fire with exposures (e.g., in building at charging station, etc.)
        - 1.4.5.Identifying compromised electrical system and battery packs
    - 1.5. Establish an information hotline (similar to Chemtrec)
- 2. Training Materials
    - 2.1. Include basic overview information on vehicles and vehicle technology
    - 2.2. Include first responder at training material design phase
    - 2.3. Focus on specific audience (e.g., fire fighter, incident commander, instructor, etc.)
    - 2.4. Training materials characteristics
        - 2.4.1.Free and on Internet
        - 2.4.2.Accurate and up-to-date
        - 2.4.3.Standardized program
        - 2.4.4.Peer-reviewed and credible
        - 2.4.5.Reflect real world training needs
        - 2.4.6.Have NFA endorsement
    - 2.5. Proactively address each vehicle class (e.g., EV, HEV, PEV, PHEV, etc.)
    - 2.6. Develop generic information that can be readily implemented
    - 2.7. Remind fire service of conventional fire fighting and rescue tactics
- 3. Other
    - 3.1. Provide emergency responder information before introduction of product line or technology
    - 3.2. Develop a hazard assessment procedure to clarify safe conditions

D. What are the known or potential topics of technical debate?

- 1. Vehicle Features
    - 1.1. New types of batteries
    - 1.2. High voltage devices, components and systems
    - 1.3. Methods for rapid vehicle identification (e.g., OnStar type dispatch)
- 2. Fire Fighting Tactics
    - 2.1. Residential fires with vehicles in garage
    - 2.2. Extinguishment of battery fires
    - 2.3. Methods for powering-down vehicle
- 3. Regulatory
    - 3.1. Formats for vehicle emergency response guides
    - 3.2. Vehicle identification and labeling
    - 3.3. High voltage component and electrical cable coloring
    - 3.4. Emergency shut-off locations

I. FUTURE TRENDS

A. Based on current technological trends, what are the greatest anticipated future hazards?

- 1. Vehicle Features
    - 1.1. Battery and capacitor technology (e.g., high capacity storage)
    - 1.2. Hybrid vehicles other than ICE/Electric (e.g., hydrogen fuel cell, other fuels, etc.)
    - 1.3. Vehicle photovoltaic systems
    - 1.4. After market conversions (e.g., non-OEM)
- 2. Emergency Responder
    - 2.1. Need standardization
    - 2.2. Hazardous material issues
- 3. Built Infrastructure Electrical System

    - 3.1. Interface between vehicles and charging stations/structures
    - 3.2. Vehicle electrical systems supplying electric grid

B. <u>How should fire service be addressing this topic in 5 years? 10 years?</u>

1. <u>Operation and Training</u>
    - 1.1. Transmit detailed emergency response info via dispatch (e.g., enhanced OnStar)
    - 1.2. Establish training program and support materials, that is:
        - 1.2.1. Readily accessible to all emergency responders
        - 1.2.2. Credible and peer-reviewed
        - 1.2.3. Practical and realistic
2. <u>Data Management</u>
    - 2.1. Establish universal, credible, continually updated venue with vehicle data for emergency responders
    - 2.2. Establish system for improved loss and injury data
3. <u>Standardization</u>
    - 3.1. Establish better SAE/NFPA/Other interaction (at multiple levels)
    - 3.2. Develop consensus on all operational technical questions (e.g., battery fire extinguishment, optimum power-down approach, etc.)
    - 3.3. Standardize essential information for emergency responders

C. <u>What constituent groups and/or organizations need to be involved?</u>

1. <u>Public Organizations</u>
    - 1.1. Emergency responder representatives
        - 1.1.1. Fire service
            - 1.1.1.1. Membership organizations (e.g., IAFC, IAFF, NVFC, etc.)
            - 1.1.1.2. Training organizations (e.g., NAFTD, NFA, etc.)
        - 1.1.2. EMS and law enforcement
    - 1.2. Federal government
        - 1.2.1. DOT, including NHTSA and PHMSA
        - 1.2.2. DOE and NREL (and other DOE related organizations)
        - 1.2.3. NTSB
        - 1.2.4. OSHA
    - 1.3. Authorities Having Jurisdiction (AHJs)
        - 1.3.1. Fire Marshals (e.g., IFAM, NASFM, etc.)
        - 1.3.2. Electrical inspectors (e.g., IAEI, etc.)
        - 1.3.3. Building officials
2. <u>Private Organizations</u>
    - 2.1. Conformity assessment and product approval organizations (e.g., UL, etc.)
    - 2.2. Industry
        - 2.2.1. Associations and membership organizations (e.g., SAE, IEEE, etc.)
        - 2.2.2. Vehicle manufacturers (e.g., AAM, AAIM, etc.)
        - 2.2.3. Battery manufacturers
        - 2.2.4. Other related manufacturers (e.g., OnStar type organizations, etc.)
    - 2.3. Insurance, including Insurance Institute for Highway Safety (IIHS)
    - 2.4. Building users/owners (with charging stations)
3. <u>Others</u>
    - 3.1. Dispatch community (e.g., APCO, etc.)
    - 3.2. Utility representation (e.g., EEI, etc.)

    - 3.3. Labor unions (e.g., IAFF, IBEW, etc.)
    - 3.4. Codes and standard developing organizations (NFPA, SAE, IEEE, ICC, ISO, IEC, etc.)
    - 3.5. Applicable consumer membership organizations (e.g., AAA, Plug-In America, etc.)
    - 3.6. Applicable research organizations (e.g., AAA Foundation, IIHS, etc.)
    - 3.7. International representation

I. OTHER ISSUES

A. What other case study events have not already mentioned, and what are lessons learned?

1. Investigation process
    - 1.1. Provide case study follow-up process (e.g., fire investigation, NIOSH type investigations)
    - 1.2. Consider approach similar to NHTSA Investigation Team for air bags
2. Data Collection Methods
    - 2.1. Clarify available NHTSA data
    - 2.2. Consider establishing Fire-Fighter-Near-Miss type website, but specifically for EVs/HEVs
    - 2.3. Establish process parameters for data collection
    - 2.4. Obtain and analyze available insurance loss data
3. Other Issues
    - 3.1. Events related to removal, recovery, and salvage (e.g., tow operators, etc.)

B. What specific updates/additions/changes need to be addressed in codes and standards?

1. Vehicle Standards
    - 1.1. Implement consistent vehicle identification format (e.g., VSDS concept, etc.)
    - 1.2. Better coordinate emergency responder concerns into vehicle designs
        - 1.2.1. Electrical cable coloring
        - 1.2.2. Emergency shut-off locations
        - 1.2.3. Hazard labeling
2. Fire Service Standards
    - 2.1. Establish consistent formats for vehicle ERGs
    - 2.2. Update emergency responder professional qualification standards
    - 2.3. Overhaul and post-fire situations
3. Codes for Built Infrastructure
    - 3.1. Address charging station interface from emergency responder perspective (e.g., location, disconnects, etc.)
    - 3.2. Consider markings/labeling for buildings with charging stations
4. Other Codes and Standards
    - 4.1. Data collection systems (e.g., NFIRS, FIDO, etc.)
    - 4.2. Fire investigations (e.g., NFPA 921, etc.)
5. Other Issues
    - 5.1. Address after-market conversions and non-OEM vehicles
    - 5.2. Consider age for charging station interface
    - 5.3. Provide travel support for emergency responder participation in applicable codes and standards processes
    - 5.4. Consider joint partnerships between standard-developing organizations (e.g., NFPA and SAE, etc.)

C. What single message should the fire service express on this topic?

1. Emergency Responder Tactics
    - 1.1. Establish standardized methods and approaches; don’t become complacent
    - 1.2. This is no different than other conventional technology advancements
    - 1.3. Default to worst-case approach until proven otherwise
    - 1.4. Enable electronic transmittal of accurate dispatch data to emergency responders
2. Code Development
    - 2.1. Standardize certain vehicle features (e.g., power-down process, labeling, cable color, etc.)
    - 2.2. Clarify consensus on fire service technical issues (e.g., battery fires, etc.)
3. Education and Training
    - 3.1. Focus on simplified, straightforward materials
    - 3.2. Provide affordable continuing education
    - 3.3. Stay tuned; technical content is continually being updated
    - 3.4. Establish standardized methods and approaches

Figure 5-13: Workshop Working Group Summary

(This page left intentionally blank)

6. SUMMARY OBSERVATIONS

This report assembles best practice information for fire fighters and fireground incident commanders to assist in their decision making process with emergency events involving electric drive and hybrid electric vehicles. This includes vehicles intended for roadway passenger use, and involving fire and/or rescue emergency situations either on the roadway or at charging/docking stations (e.g., garages).

This report collects and analyzes applicable scientific studies, training guidance, case study reports and loss data, and available emergency response guidance relating to electric drive and hybrid electric vehicles. The project deliverables are intended to serve as the basis for training program development by others.

A critical task in this project was the interactive one-day workshop involving fire service and other subject-matter experts. This provided a detailed review and assessment of the information in this report, and generated a summary of the fundamental principles and key details relating to issues such as training needs, areas needing further research, revisions to codes and standards, and other applicable topics. The complete results are summarized in Figure 5-13 in the previous section.

The workshop review was coordinated around ten basic questions, and the collective response to these ten questions focuses on the core basics of this issue. Of particular interest is the tenth and final question that asked each break-out session: "What single message should the fire service express on this topic?" This question helped to clarify and highlight the most important issues arising throughout the entire project (as well as during the workshop review).

The following is a summary of the most important issues for emergency responders that need to considered and/or addressed for electric drive or hybrid electric vehicles:

Emergency Responder Tactics

- <u>Establish standardized methods and approaches; Don't become complacent.</u> Standardized methods and approaches based on accurate and competent information that is simple, clear, consistent, credible, and readily accessible is needed if guidance information is expected to reach the mass audience of emergency responders addressing this topic. In establishing these standardized methods and approaches, care should be taken not to become complacent in assuming obvious technical, training, and educational details.

- <u>This is no different than other conventional technology advancements.</u> This topic is yet another new and evolving safety-related issue that requires attention from the emergency response community. While it is important and certainly deserves attention, on the other hand there is no need to panic or create a sense of unfounded fear. Emergency response personnel should approach this overall subject area as yet another topic that they need to address with awareness, caution, and understanding to assure that conditions are maintained as safe as possible for all involved.

- Default to worst-case approach until proven otherwise. For any technical concerns that remain questionable (e.g., cutting certain vehicle cabling during extrication, extinguishing specific battery fires, etc.) should be based on safely addressing the worst case situations, unless credible and accurate information supports alternative methods and approaches.

- Enable electronic transmittal of accurate dispatch data to emergency responders. A strong desire exists to provide a universal method of quick vehicle identification for emergency responders. While this could include labels or emblems on the vehicle itself, the optimum approach is to provide electronic transmittal of critical emergency response information, possibly directly from the dispatcher to the emergency responders prior to arrival at the scene. This technology exists today (e.g., OnStar-type data transmittal), and it is reported that the European Union is planning to require this emergency responder technology approach in all European motor vehicles over a phase-in period covering the next several years.

Code Development

- Standardize certain vehicle features (e.g., power-down process, labeling, cable color, etc.). Standardization of certain vehicle features of specific interest to emergency responders needs to be better coordinated, and direct consensus input for the emergency response community is essential in the codes and standards revision process. Specific attention is needed to promote consistency for technical details such as the power-down process, vehicle labeling, and electrical cable coloring, within the bounds of what the competitive automobile marketplace will allow. Emergency first responders also need to standardize the specific emergency response information they desire, and the format and delivery mechanisms for providing this information.

- Clarify consensus on fire service technical issues (e.g., battery fires, etc.). All technical methods and approaches important to emergency responders that do not have universal consensus (e.g., recommended approach to extinguishing certain types of battery fires), requires an ongoing mechanism to readily and transparently establish credible consensus on the topic.

Education and Training

- Focus on simplified, straightforward materials. Training and education materials for emergency first responders should attempt to be simple, straightforward and provided in a format that is easily understandable, while remaining informative and credible.

- Provide affordable continuing education. The availability of the training and education materials on this topic need to be affordable and readily obtainable for the emergency response community if there is to be any real expectation of their widespread use.

- Stay tuned; technical content is continually being updated. A critical aspect of providing accurate and technically valid information for emergency responders is that it must be continually up-dated. An on-going, living core-conduit of vehicle technical information needs to be available so that emergency responders can universally access the latest appropriate response guide information as new and modified vehicles appear in the marketplace.

- Establish standardized methods and approaches. Methods and approaches used by all emergency responders, including the job performance requirements for all anticipated applicable tasks (e.g., fire fighter, EMS technician, incident commander, investigator, instructor, etc.), need to be standardized to universally coordinate best practices.

(This page left intentionally blank)

7. BIBLIOGRAPHY

The following reference sources are cited throughout this report:

1) "Alternative Energy", Encyclopedia Britannica, website: www.britannica.com/EBchecked/topic/17668/renewable-energy, cited: 17 November 2009
2) Berman, B. (editor), "History of Hybrid Vehicles", Hybrid Cars: Auto Alternatives for the 21st Century, website: www.hybridcars.com/history/history-of-hybrid-vehicles.html, cited: 24 Nov 2009
3) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pg. 198
4) Westbrook, M.H., "The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars", Institution of Electrical Engineers, University Press, Cambridge England, chapter 10, pg. 143, 2005
5) Leitman, S., "Build Your Own Plug-in Hybrid Electric Vehicle", McGraw Hill NY, Chapter 3, pg. 29, 2009
6) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pg. 199
7) Long, R.T., Colwell, J.D., Ray, R., Grossmann, H.L., Thomas, B., Strassburger, R., "Passenger Vehicle Fires", Fire Protection Handbook, Section 21, Chapter 1, 20th edition, National Fire Protection Association, Quincy MA, pg. 21-4, 2008
8) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pg. 199
9) Leitman, S., "Build Your Own Plug-in Hybrid Electric Vehicle", McGraw Hill NY, Chapter 3, pg. 30, 2009
10) Rivkin, C.H., "Vehicle Fueling Using Gaseous Fuels", Fire Protection Handbook, Section 21, Chapter 4, 20th edition, National Fire Protection Association, Quincy MA, pg. 21-41, 2008
11) Yacobucci, B., Alternative Fuels and Advanced Technology Vehicles: Issues in Congress, Resources Sciences and Industry Division, Congressional Research Service, IB10128, 9 Sept 2004, website: http://ncseonline.org/NLE/CRSreports/04Sep/IB10128.pdf, cited: 17 November 2009
12) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pg. 200
13) Leitman, S., "Build Your Own Plug-in Hybrid Electric Vehicle", McGraw Hill NY, Chapter 1, pg. 8, 2009
14) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009
15) SAE J1715, Hybrid Electric Vehicle & Electric Vehicle Terminology, Section 3.63, Society of Automotive Engineers, Detroit MI, Feb 2008
16) NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, Article 625.2, 2008 Edition
17) EV Glossary, Electric Auto Association, website: www.eaaev.org/Info/eaaglossary.html, cited: 14 November 2009

18) "Introducing Chevrolet Volt", Website: www.chevrolet.com/pages/open/default/future/volt.do?seo=goo_|_2009_Chevy_Awareness_|_IMG_Chevy_Volt_Phase_2_Branded_|_Volt_HV_|_volt, cited: 18 March 2010

19) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

20) 49 CFR Part 571, U.S Dept. of Transportation, National Highway Traffic Safety Administration, Docket No. NHTSA 98-3949, website: www.nhtsa.dot.gov/cars/rules/rulings/lsv/lsv.html, cited: 18 Dec 2009

21) EV Glossary, Electric Auto Association, website: www.eaaev.org/Info/eaaglossary.html, cited: 14 November 2009

22) 49 CFR Part 571, U.S Dept. of Transportation, National Highway Traffic Safety Administration, Docket No. NHTSA 98-3949, website: www.nhtsa.dot.gov/cars/rules/rulings/lsv/lsv.html, cited: 18 Dec 2009

23) "Advanced Vehicle Testing Activity: Neighborhood Electric Vehicles", U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, website: http://www1.eere.energy.gov/vehiclesandfuels/avta/light_duty/nev/index.html, cited 11 November 2009

24) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

25) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

26) "Truck", Wordnet, website: wordnetweb.princeton.edu/perl/webwn?s=truck, cited: 30 November 2009

27) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

28) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

29) Westbrook, M.H., "The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars", Institution of Electrical Engineers, University Press, Cambridge England, pg. 145, 2005

30) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pgs. 202-203

31) "The Hybrid Car Battery: A Definitive Guide", Hybrid Cars; Auto Alternatives for the 21st Century, 6 Nov 2008, website: www.hybridcars.com/hybrid-car-battery, cited: 4 Dec 2009

32) German, J.M., "Hybrid Electric Vehicles", Encyclopedia of Energy, Volume 3 Gl-Ma, Elsevier Academic Press, New York NY, 2004, pgs. 202-203

33) Chapter 52, Stationary Storage Battery Systems, NFPA 1, *Fire Code*, National Fire Protection Association, Quincy MA, 2009

34) Section 608, IFC, International Fire Code, International Code Council, Country Club Hills IL, 2006 edition

35) Chapter 52, Stationary Storage Battery Systems, NFPA 1, *Fire Code*, National Fire Protection Association, Quincy MA, 2009 edition

36) Ponticel, P., "SAE Forms Committee to Write Battery Standards", SAE Update, Society of Automotive Engineers, January 2010, pg. 17

37) "Hybrid Vehicles", www.FuelEconomy.Gov, U.S. Dept of Energy & U.S. Environmental Protection Agency, website: www.fueleconomy.gov/feg/hybrid_sbs.shtml, cited: 18 Dec 2009
38) "Hybrid Vehicles", www.FuelEconomy.Gov, U.S. Dept of Energy & U.S. Environmental Protection Agency, website: www.fueleconomy.gov/feg/hybrid_sbs.shtml, cited: 18 Dec 2009
39) Hamilton, T., “Battery Breakthrough?”, Technology Review, MIT, Cambridge MA, 22 Jan 2007, website: www.technologyreview.com/biztech/18086/, cited: 4 Dec 2009
40) Ehsani, M., Gao, Y., Emadi, A., “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, 2nd edition, CRC Press, Boca Raton FL, 2010, pg. 123
41) Leitman, S., "Build Your Own Plug in Hybrid Electric Vehicle", chapter 1, page 6
42) Husain, I., “Electric and Hybrid Vehicles: Design Fundamentals”, CRC Press, New York NY, chap. 10, pg. 243
43) Technical Committee 69, Electric Road Vehicles, International Electrotechnical Commission
44) Westbrook, M.H., "The Electric Car: Development and Future of Battery Hybrid and Fuel-Cell Cars,” The Institution of Electrical Engineers, Chapter 10 page 142
45) Ehsani, M., Gao, Y., Emadi, A., “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles”, 2nd edition, CRC Press, Boca Raton FL, 2010, pg. 123
46) Berman, B., “Hybrid Terms”, Hybrid Cars: Auto Alternatives for the 21st Century”, website: www.hybridcars.com/types-systems/hybrid-terms.html, cited: 17 Nov 2000
47) Berman, B., “Hybrid Terms”, Hybrid Cars: Auto Alternatives for the 21st Century”, website: www.hybridcars.com/types-systems/hybrid-terms.html, cited: 17 Nov 2000
48) Husain, I., “Electric and Hybrid Vehicles: Design Fundamentals”, CRC Press, New York NY, chap. 10, pg. 243
49) Husain, I., “Electric and Hybrid Vehicles: Design Fundamentals”, CRC Press, New York NY, chap. 10, pg. 245
50) Berman, B. (editor), “Hybrid Cars: Auto Alternatives for the 21st Century”, website: www.hybridcars.com/electric-car, cited: 24 Nov 2009
51) Voelcker, J., “Electric Cars Move Slowly”, Technology Review, Nov/Dec 2009, pg. 68
52) “FuelEconomy.Gov”, U.S. Department of Energy and U.S Environmental Protection Agency, website: www.fueleconomy.gov/feg/hybrid_sbs.shtml, cited: 4 Dec 2009
53) Chase, K.J., “Automakers Go Green, But Who’s Buying?”, Boston Globe, 4 Dec 2009
54) “FuelEconomy.Gov”, U.S. Department of Energy and U.S Environmental Protection Agency, website: www.fueleconomy.gov/feg/hybrid_sbs.shtml, cited: 4 Dec 2009
55) “Automotive 2020: Clarity Beyond the Chaos”, IBM Global business Solutions, IBM Global Services, Somers NY, August 2008
56) “HEV Sales by Model”, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, Website: www.afdc.energy.gov/afdc/data/vehicles.html, Cited: 23 March 2010
57) “HEV Sales by Model”, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, Website: www.afdc.energy.gov/afdc/data/vehicles.html, Cited: 23 March 2010
58) Davis S.C., Diegel S.W., Boundy R.G., “Transportation Energy Data Book”, 28th Edition, ORNL-6984, Table 6-1 Estimates of Alternative Vehicles in Use, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009
59) Kaho, T., “Billions for Better Cars”, Green Car Journal, Summer 2009, pg. 9
60) Davis S.C., Diegel S.W., Boundy R.G., “Transportation Energy Data Book”, 28th Edition, ORNL-6984, Table 6-1 Estimates of Alternative Vehicles in Use, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009
61) Table 10.5, “Estimated Number of Alternative-Fueled Vehicles in Use and Replacement Fuel Consumption”, Alternatives to Traditional Transportation Fuels, Energy Information

Administration, U.S. Department of Energy, Washington DC, April 2009, website: www.eia.doe.gov/emeu/aer/renew.html, cited: 14 November 2009

62) Table 10.5, "Estimated Number of Alternative-Fueled Vehicles in Use and Replacement Fuel Consumption", Alternatives to Traditional Transportation Fuels, Energy Information Administration, U.S. Department of Energy, Washington DC, April 2009, website: www.eia.doe.gov/emeu/aer/renew.html, cited: 14 November 2009

63) FHWA - U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 2007, Washington, DC, 2009, Table VM-1, website: www.fhwa.dot.gov, cited 14 November 2009

64) "Energy Policy Act of 1992", EPAct Transportation Regulatory Activities, Vehicle Technology Program, U.S. Dept of Energy, website: http://www1.eere.energy.gov/vehiclesandfuels/epact/, cited; 17 November 2009

65) "Overview of the Clean Air Act Amendment of 1990", U.S. Environmental Protection Agency, website: http://www.epa.gov/air/caa/overview.txt, cited 17 November 2009

66) "Energy Policy Act of 1992", EPAct Transportation Regulatory Activities, Vehicle Technology Program, U.S. Dept of Energy, website: http://www1.eere.energy.gov/vehiclesandfuels/epact/, cited; 17 November 2009

67) "Overview of the Clean Air Act Amendment of 1990", U.S. Environmental Protection Agency, website: http://www.epa.gov/air/caa/overview.txt, cited 17 November 2009

68) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Table 6-4 Number of Alternative Refuel Sites by State and Fuel Type, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

69) "Hybrid Vehicles", www.FuelEconomy.Gov, U.S. Dept of Energy & U.S. Environmental Protection Agency, website: www.fueleconomy.gov/feg/hybrid_sbs.shtml, cited: 4 Dec 2009

70) Table 1-16, Retail Sales New Passenger Car Sales, National Transportation Statistics, Bureau of Transportation Statistics, Research and Innovative Technology Administration, U.S. Department of Transportation, Sept 2009 website: www.bts.gov/publications/national_transportation_statistics/#chapter_1, cited: 11 Nov 2009

71) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

72) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009

73) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009

74) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

75) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009

76) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009

77) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

78) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009

79) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009

80) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

81) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009
82) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009
83) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009
84) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009
85) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009
86) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009
87) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009
88) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009
89) Long, R.T., Colwell, J.D., Ray, R., Grossmann, H.L., Thomas, B., Strassburger, R., "Passenger Vehicle Fires", Fire Protection Handbook, Section 21, Chapter 1, 20th edition, National Fire Protection Association, Quincy MA, pg. 21-3, 2008
90) Traffic Safety Facts 2005, Table 2, NHTSA's National Center for Statistics and Analysis, U.S. Department of Transportation, Washington DC, 2006, p. 15, website: http://www-nrd.nhtsa.dot.gov/Pubs/TSF2005.PDF, cited: 16 November 2009
91) "Voltage to Headlamp", section 2.5, U.S. Dept of Transportation, National Highway Traffic Safety Administration, 49 CFR Part 571, Comments on Federal Motor Vehicle Safety Standard No. 108, website: www.nhtsa.gov/cars/rules/rulings/glare.html, cited: 28 Dec 2009
92) "Hazardous Materials Commonly Found in Vehicles", U.S. Dept of Transportation, Pipeline and Hazardous Materials Safety Administration, HazMat Safety Community, Jan 2008, website: www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/dot_car_flyer.pdf, cited: 23 Nov 2009
93) "Hybrid and Emergency First Responders", Hybrid Cars: Auto Alternatives for the 21st Century, 3 Apr 2006, website: www.hybridcars.com/safety/hybrids-and-first-responders.html, cited: 2 Dec 2009
94) "Fire Service Training for Advanced Electric Drive Vehicles", Research Project at NFPA, National Fire Protection Association, Quincy MA, Feb 2010
95) Moore, R.E., The VSDS Proposal: Providing Critical Data To Rescue Personnel, Firehouse, Volume 24, Issue 7, July 1999
96) Moore, R.E., The VSDS Proposal: Providing Critical Data To Rescue Personnel, Firehouse, Volume 24, Issue 7, July 1999
97) "Injury and Death Statistics", National Safety Council, Website: www.nsc.org/news_resources/injury_and_death_statistics/Pages/InjuryDeathStatistics.aspx, Cited: 24 March 2010
98) Karter, M., Table 2, Fireground Injuries by Primary Apparent Symptom for Total Injuries and by Severity 2001-2006 Annual Average, "Patterns of Firefighter Fireground Injuries", National Fire Protection Association, Quincy MA, May 2009
99) Section K.2, Electric Shock, NFPA 70E®, *Standard for Electrical Safety in the Workplace®*, National Fire Protection Association , Quincy MA, 2009 edition
100) "Worker Death by Electrocution", A Summary of NIOSH Surveillance and Investigative Findings, CDC/NIOSH, May 1998, website: /www.cdc.gov/niosh/docs/98-131/, cited: 26 Feb 2010

101) Steiner, W., “The Fire Fighter’s Guide to Electrical Safety”, University of Missouri – Columbia, 1981, pg. 8

102) Slaughter, R., “Fundamentals of Photovoltaics for the Fire Service”, Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009

103) Section K.2, Electric Shock, NFPA 70E®, *Standard for Electrical Safety in the Workplace®,* National Fire Protection Association , Quincy MA, 2009 edition

104) IAEI Data, International Association of Electrical Inspectors, Richardson TX, 2008

105) “Worker Death by Electrocution”, A Summary of NIOSH Surveillance and Investigative Findings, CDC/NIOSH, May 1998, website: /www.cdc.gov/niosh/docs/98-131/, cited: 26 Feb 2010

106) Slaughter, R., “Fundamentals of Photovoltaics for the Fire Service”, Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009

107) NEC Training Curriculum, National Fire Protection Association, Quincy MA, 2004

108) “Hybrid Vehicle Caution”, Info-Gram, U.S. Fire Administration, 21 Apr 2005, website: www.usfa.dhs.gov/fireservice/subjects/emr-isac/infograms/ig2005/igapr2105.shtm, cited: 3 Dec 2009

109) Article 690, NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, 2009 edition

110) ANSI C84.1, *American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)*, National Electrical Manufacturers Association, Rosslyn VA, 2006 edition

111) SAE J1715, Hybrid Electric Vehicle & Electric Vehicle Terminology, Section 3.85, Society of Automotive Engineers, Detroit MI, Feb 2008

112) SAE J2344, Guidelines for Electric Vehicle Safety, Section 3.4, Society of Automotive Engineers, Detroit MI, Jun 1998

113) Table 2-17: Motor Vehicle Safety Data, National Transportation Statistics, Bureau of Transportation Statistics, Research and Innovative Technology Administration, U.S. Dept of Trans, website: www.bts.gov/publications/national_transportation_statistics/#appendix_b, cited: 11 Nov 2009

114) Karter, M.J., “Fire Loss in the United States - 2008, National Fire Protection Association, Quincy MA, Aug 2009

115) Ahrens, M., “U.S. Vehicles Trends and Patterns”, Figure 1: U.S. Vehicle Fires by Year, Fire Analysis and Research Division, National Fire Protection Association, Quincy MA, May 2009

116) Ahrens, M., “U.S. Vehicles Trends and Patterns”, Figure 2: U.S. Vehicle Deaths by Year, Fire Analysis and Research Division, National Fire Protection Association, Quincy MA, May 2009

117) Ahrens, M., “U.S. Vehicles Trends and Patterns”, Figure 5: Highway Vehicle Fires and Deaths by Fire Causal Factor, Fire Analysis and Research Division, National Fire Protection Association, Quincy MA, May 2009

118) Ahrens, M., “U.S. Vehicles Trends and Patterns”, Figure 7: Area of Origin in Vehicle Fires, by Fire Causal Factor, Fire Analysis and Research Division, National Fire Protection Association, Quincy MA, May 2009

119) “National Fire Fighter Near Miss Reporting System”, Grouped Reports: Electrical/Power-Lines/Vehicle-Fires, website: www.firefighternearmiss.com, cited: 24 March 2010

120) “National Fire Fighter Near Miss Reporting System”, Report # 06-0000548, website: www.firefighternearmiss.com, cited: 2 Dec 2009

121) “National Fire Fighter Near Miss Reporting System”, Report # 09-0000914, website: www.firefighternearmiss.com, cited: 2 Dec 2009

122) Davis S.C., Diegel S.W., Boundy R.G., “Transportation Energy Data Book”, 28th Edition, ORNL-6984, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009)

123) Blake, C., Buttner, W., Rivkin, C., "Vehicle Codes and Standards: Overview and Gap Analysis", National Renewable Energy Laboratory, Technical Report, NREL/TP-560-47336, February 2010

124) Kowsowski, M., "Evaluation of Codes and Standards for Electric and Plug-In Vehicles", National Renewable Energy Laboratory, Technical Report, NREL/TP-560-47336 Appendix II, February 2010

125) “RFP Communication Support for First Responder Electrical Vehicle Training Program”, National Fire Protection Association, Quincy MA, website: www.nfpa.org/assets/files//Press%20Room/NFPAElectricalVehicleCommunicationRFP.pdf, cited: 25 Feb 2010

126) ComCare: Emergency Response Alliance, Washington DC, website: www.comcare.org/Initiatives.html, cited: 26 Feb 2010

127) “Developing Standard Operating Procedures”, FA-197, U.S. Fire Administration, Federal Emergency Management Agency, Washington DC, Dec. 1999, Chap. 1, pg. 2, website: www.usfa.dhs.gov/downloads/pdf/publications/fa-197-508.pdf, cited: 23 Dec 2009

128) NFPA 1521, *Standard for Fire Department Safety Officer*, National Fire Protection Association, Quincy MA, sections 3.3.47 & A3.3.48, 2008 Edition)

129) NFPA 1521, *Standard for Fire Department Safety Officer*, National Fire Protection Association, Quincy MA, sections 3.3.48 & A.3.3.48, 2008 Edition

130) “Developing Standard Operating Procedures”, FA-197, U.S. Fire Administration, Federal Emergency Management Agency, Washington DC, Dec. 1999, Chap. 1, pg. 2, website: www.usfa.dhs.gov/downloads/pdf/publications/fa-197-508.pdf, cited: 23 Dec 2009

131) “About Us”, International Fire Service Training Association”, Stillwater OK, Website: imis-ext.osufpp.org/imispublic/Content/NavigationMenu/AboutUs/Our75YearHistory/default.htm, cited: 17 Nov 2009

132) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 Nov 2009

133) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 Nov 2009

134) “About Us”, International Fire Service Training Association, Stillwater OK, website: www.ifsta.org, cited:17 Nov 2009

135) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 Nov 2009

136) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 Nov 2009)

137) National Fire Academy, Emmitsburg MD, US Fire Administration, website: www.usfa.dhs.gov/nfa/, cited: 4 August 2009

138) “America Burning: The Report of the National Commission on Fire Prevention and Control”, The National Commission on Fire Prevention and Control, U.S. Government Printing Office, pg. xi, 1973

139) “Endorsed Courses”, USFA National Fire Academy, Emmitsburg MD, website: www.usfa.dhs.gov/nfa/endorsed/, cited: 5 August 2009

140) “Hydrogen Safety for First Responders”, U.S. Department of Energy, Washington DC, website: www.hydrogen.energy.gov/firstresponders.html, cited: 4 August 2009

141) “Introduction to Hydrogen for Code Officials”, U.S. Department of Energy, Washington DC, website: www.hydrogen.energy.gov/code_official_training.html, cited: 4 August 2009

142) TRADE, National Fire Academy, U.S. Fire Administration, website: www.usfa.dhs.gov/nfa/trade/index.shtm, cited: 24 July 2009

143) “Hybrid and Emergency First Responders”, Hybrid Cars: Auto Alternatives for the 21st Century, 3 Apr 2006, website: www.hybridcars.com/safety/hybrids-and-first-responders.html, cited: 2 Dec 2009

144) NFPA 921, *Guide for Fire and Explosion Investigations*, Chapter 25 Motor Vehicle Fires, National Fire Protection Association, Quincy MA, 2008 Edition)

145) NFPA 921, *Guide for Fire and Explosion Investigations*, Chapter 25 Motor Vehicle Fires, National Fire Protection Association, Quincy MA, 2008 Edition

146) Wimer, D.R., “Hybrid Vehicle Incidents”, Size Up, New York State Association of Fire Chiefs, Issue 3, 2009, pgs 30-32, website: www.nysfirechiefs.com/Sizeupmagazine.php, cited: 26 Feb 2010

147) “Hybrid Vehicle Caution”, Info-Gram, U.S. Fire Administration, 21 Apr 2005, website: www.usfa.dhs.gov/fireservice/subjects/emr-isac/infograms/ig2005/igapr2105.shtm, cited: 23 Dec 2009

148) Wimer, D.R., “Hybrid Vehicle Incidents”, Size Up, New York State Association of Fire Chiefs, Issue 3, 2009, pgs 30-32, website: www.nysfirechiefs.com/Sizeupmagazine.php, cited: 26 Feb 2010

149) “Hybrid Myths”, Hybrid Manufacturer's Emergency Responder Links, Extrication.Com, website: www.extrication.com/ERG.htm#Hybrid_Myths, cited: 14 Dec 2009

150) “Hybrid Vehicle Caution”, Info-Gram, U.S. Fire Administration, 21 Apr 2005, website: www.usfa.dhs.gov/fireservice/subjects/emr-isac/infograms/ig2005/igapr2105.shtm, cited: 23 Dec 2009

151) NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, Chapter 8 Vehicle and Machinery Search and Rescue, National Fire Protection Association, Quincy MA, 2004 Edition

152) NFPA 1670, *Standard on Operations and Training for Technical Search and Rescue Incidents*, Chapter 8 Vehicle and Machinery Search and Rescue, National Fire Protection Association, Quincy MA, 2004 Edition

153) “Hybrid Vehicle Caution”, Infogram, U.S. Fire Administration, 30 Nov 2006, website: www.usfa.dhs.gov/fireservice/subjects/emr-isac/infograms/ig2006/113006.shtm, cited: 23 Dec 2009

154) Lithium Ion Batteries, Guide # 147, Emergency Response Guidebook 2008, U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Website: www.phmsa.dot.gov/hazmat/library/erg, cited 19 Mar 2010

155) Emge, A., “Karlstein am Main: Grosbrand eines Batteriemontagezentrums”, BrandSchutz,Deutsche Feuerwehr-Zeitung, January 2009, pg 37-42

156) “Toxico, Inc, Begins Fire Clean Up Operations”, Media Advisory, November 9 2009, Website: www.toxco.com, cited 23Mar 2010

157) Slaughter, R., “Fundamentals of Photovoltaics for the Fire Service”, Sept 2006, website: www.osfm.fire.ca.gov/training/photovoltaics.php, cited: 28 Dec 2009

158) Figure Q.1.2.3, NFPA 1®, *Fire Code*, National Fire Protection Association, Quincy MA, 2009 edition

159) Figure Q.1.2.3, NFPA 1®, *Fire Code*, National Fire Protection Association, Quincy MA, 2009 edition

160) Appendix C List of Acronyms and Initialisms, BTS Dictionary, Bureau of Transportation Statistics, Research and Innovative Technology Administration, U.S. Department of Transportation, website: www.bts.gov/publications/national_transportation_statistics/html/appendix_b.html, cited: 10 Nov 2009

161) Appendix B Glossary, BTS Dictionary, Bureau of Transportation Statistics, Research and Innovative Technology Administration, U.S. Department of Transportation, website: www.bts.gov/publications/national_transportation_statistics/html/appendix_b.html, cited: 11 Nov 2009

162) NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, National Fire Protection Association, Quincy MA, section 3.3.3, 2008 Edition

163) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

164) SAE J1715, Hybrid Electric Vehicle & Electric Vehicle Terminology, Section 3.8, Society of Automotive Engineers, Detroit MI, Feb 2008

165) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

166) EV Glossary, Electric Auto Association, website: www.eaaev.org/Info/eaaglossary.html, cited: 14 Nov 2009

167) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

168) Leitman, S., "Build Your Own Plug-in Hybrid Electric Vehicle", McGraw Hill NY, Chapter 1, pg. 8, 2009

169) Glossary, Energy Information Administration, Official Energy Statistics from the U.S. Government, website: www.eia.doe.gov/glossary/, cited: 11 Nov 2009

170) Glossary, Energy Information Administration, Official Energy Statistics from the U.S. Government, website: www.eia.doe.gov/glossary/, cited: 11 Nov 2009

171) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

172) SAE J1715, Hybrid Electric Vehicle & Electric Vehicle Terminology, Section 3.63, Society of Automotive Engineers, Detroit MI, Feb 2008

173) NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, Article 625.2, 2008 Edition

174) SAE J1715, Hybrid Electric Vehicle & Electric Vehicle Terminology, Section 3.74, Society of Automotive Engineers, Detroit MI, Feb 2008

175) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

176) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

177) NFPA 70®, *National Electrical Code®*, National Fire Protection Association, Quincy MA, Article 690.2, 2008 Edition

178) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

179) EV Glossary, Electric Auto Association, website: www.eaaev.org/Info/eaaglossary.html, cited: 14 November 2009

180) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

181) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

182) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

183) U.S. Code 49USC30102, Title 49 – Transportation, Subtitle VI – Motor Vehicle and Driver Programs, Chapter 301 – Motor Vehicle Safety, Subchapter I, Page 470-471, website: www.gpoaccess.gov, cited 11 Nov 2009

184) U.S. Code 49USC30102, Title 49 – Transportation, Subtitle VI – Motor Vehicle and Driver Programs, Chapter 301 – Motor Vehicle Safety, Subchapter I, Page 470-471, website: www.gpoaccess.gov, cited 11 Nov 2009

185) U.S. Code 49USC30102, Title 49 – Transportation, Subtitle VI – Motor Vehicle and Driver Programs, Chapter 301 – Motor Vehicle Safety, Subchapter I, Page 470-471, website: www.gpoaccess.gov, cited 11 Nov 2009

186) U.S. Code 49USC30102, Title 49 – Transportation, Subtitle VI – Motor Vehicle and Driver Programs, Chapter 301 – Motor Vehicle Safety, Subchapter I, Page 470-471, website: www.gpoaccess.gov, cited 11 Nov 2009

187) 49 CFR Part 571, U.S Dept. of Transportation, National Highway Traffic Safety Administration, Docket No. NHTSA 98-3949, website: www.nhtsa.dot.gov/cars/rules/rulings/lsv/lsv.html, cited: 18 Dec 2009

188) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

189) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

190) NFPA 52, *Vehicular Fuel Systems Code*, National Fire Protection Association, Quincy MA, Section 3.3.34, 2006 Edition

191) Title 49 Transportation, Part 523.4 Vehicle Classification, Code of Federal Regulations, Electronic Code of Federal Regulations, U.S. Government Printing Office, Washington DC

192) EV Glossary, Electric Auto Association, website: www.eaaev.org/Info/eaaglossary.html, cited: 14 November 2009

193) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

194) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

195) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

196) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

197) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

198) Glossary, Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy, website: www.afdc.energy.gov/afdc/glossary.html, cited: 11 Nov 2009

199) Davis S.C., Diegel S.W., Boundy R.G., "Transportation Energy Data Book", 28th Edition, ORNL-6984, Annex C: Glossary, Oak Ridge National Laboratory, U.S. Dept of Energy, 2009, website: cta.ornl.gov/data, cited: 13 Nov 2009

200) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

201) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009

202) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009

203) Berman, B. (editor), "Hybrid Cars: Auto Alternatives for the 21st Century", website: www.hybridcars.com/electric-car, cited: 24 Nov 2009

204) Morrison, C., "30 Electric Car Companies Ready to Take Over the Road", GreenBeat, 10 Jan 2008, website: green.venturebeat.com/2008/01/10/27-electric-cars-companies-ready-to-take-over-the-road/, cited: 24 Nov 2009

205) "X-Prize Cars", website: www.xprizecars.com, cited: 24 Nov 2009

206) Karter, M.J., Stein, G.P., "U.S. Fire Department Profile Through 2007", National Fire Protection Association, Quincy MA, Nov 2008, pg. 1

207) Nolan, D.P., Encyclopedia of Fire Protection", Thompson Delmar Learning, Clifton Park NY, 2nd edition, 2006, pg. 91

208) "Origin and Development", NFPA 1961, *Standard on Fire Hose*, National Fire Protection Association, Quincy MA, 2007 edition) "Origin and Development", NFPA 1410, *Standard on Training for Initial Emergency Scene Operations*, National Fire Protection Association, Quincy MA, 2005 edition

210) "2008 State & Provincial List of Certifications to NFPA Professional Qualifications Standards", NFPA Public Fire Protection Division, National Fire Protection Association, Quincy MA, July 2009

211) "DHS adopts NFPA standards for responders to hazardous materials/weapons of mass destruction incidents", News Release, National Fire Protection Association, Quincy MA, 3 Sep 2008, website: www.nfpa.org/newsReleaseDetails.asp?categoryID=488&itemID=40386, cited: 18 Dec 2009

212) Grant, C.C., "Research Renaissance", NFPA Journal, National Fire Protection Association, Mar/Apr 2009, pg. 54

213) Laughlin, J., "Training Programs for Fire and Emergency Service Personnel", Fire Protection Handbook, 20th edition, Section 12, Chapter 10, National Fire Protection Association, Quincy MA, 2008, pg 12-166

214) "About Us", International Fire Service Training Association", Stillwater OK, Website: imis-ext.osufpp.org/imispublic/Content/NavigationMenu/AboutUs/Our75YearHistory/default.htm, cited: 3 August 2009

215) Jones and Bartlett Publishing, Sudbury MA, Website: Fire.jbpub.com, cited: 17 August 2009

216) DELMAR CENGAGE Learning, Florence KY, Website: www.delmarlearning.com, cited: 17 August 2009

217) Laughlin, J., "Training Programs for Fire and Emergency Service Personnel", Fire Protection Handbook, 20th edition, Section 12, Chapter 10, National Fire Protection Association, Quincy MA, 2008, pg 12-169

218) NFPA 1000, *Standard for Fire Service Professional Qualifications Accreditation and Certification Systems*, National Fire Protection Association, Quincy MA, section 3.3.2 through 3.3.6, 2006 edition

219) NFPA 1000, *Standard for Fire Service Professional Qualifications Accreditation and Certification Systems*, National Fire Protection Association, Quincy MA, section 3.3.1 through 3.3.5, 2006 edition

220) NFPA 1000, Standard *for Fire Service Professional Qualifications Accreditation and Certification Systems*, National Fire Protection Association, Quincy MA, section 3.3.1, 2006 edition

221) NFPA 1000, Standard *for Fire Service Professional Qualifications Accreditation and Certification Systems*, National Fire Protection Association, Quincy MA, section 3.3.3, 2006 edition

222) NFPA 1000, *Standard for Fire Service Professional Qualifications Accreditation and Certification Systems*, National Fire Protection Association, Quincy MA, section 3.3.5, 2006 edition

(This page left intentionally blank)

Annex A: List of Applicable Acronyms

The following are the acronyms and initials used throughout this report, and/or that are commonly used relative to the subject matter applicable to this report:[160]

Table A-1: List of Acronyms

Acronym	Full Title or Description
AAA	American Automobile Association
AADT	Annual Average Daily Traffic
AAMA	American Automobile Manufacturers Association
AFV	Alternative Fuel Vehicle
ALVW	Adjusted Loaded Vehicle Weight
APTA	American Public Transit Association
ATS	American Travel Survey
ATV	All-Terrain Vehicle
BEA	Bureau of Economic Analysis
BEV	Battery Electric Vehicle
BTS	Bureau of Transportation Statistics
CARB	California Air Resource Board
CFR	U.S. Code of Federal Regulations
CFV	Clean Fleet Vehicle
CNG	Compressed Natural Gas
CVS	Certification Vehicle Standard
DFV	Dual Fuel Vehicle
EC	Electric Car
EHV	Electric Hybrid Vehicle
EIA	Energy Information Administration
EMV	Electric Motor Vehicle
EV	Electric Vehicle
FARS	Fatality Analysis Reporting System Database
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FTP	Federal Test Procedure
GES	General Estimates System
GIS	Geographic Information System
GVWR	Gross Vehicle Weight Rating
HEV	Hybrid Electric Vehicle
HPMS	Highway Performance Monitoring System

Acronym	Full Title or Description
ICC	Interstate Commerce Commission
ICE	Internal Combustion Engine
ILEV	Inherently Low Emission Vehicle
LEV	Low Emission Vehicle
LDT	Light-Duty Truck
LDV	Light Duty Vehicle
LPG	Liquefied Petroleum Gas
LVW	Loaded Vehicle Weight
MCMIS	Motor Carrier Management Information System
MIC	Motorcycle Industry Council, Inc.
MDPV	Medium-Duty Passenger Vehicles
MDV	Medium Duty Vehicle
MV	Motor Vehicle
MVMA	Motor Vehicle Manufacturers Association
NDC	Navigation Data Center
NEV	Neighborhood Electric Vehicle
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NOPS	National Operations Center
NOPUS	National Occupant Protection Use Survey
NTD	National Transit Database
NTS	National Transportation Statistics
NTSB	National Transportation Safety Board
OEM	Original Equipment Manufacturer
OIG	Office of the Inspector General
OST	Office of the Secretary of Transportation
PHEV	Plug-in Hybrid Electric Vehicle
PIRS	Pollution Incident Reporting System
PSI	Pollutant Standard Index
RSPA	Research and Special Programs Administration
SAMIS	Safety Management Information Statistics
SHA	State Highway Agencies
STB	Surface Transportation Board
SULEV	Super Ultra Low Emission Vehicle
TLEV	Transitional Low Emission Vehicle
TMG	Traffic Monitoring Guide
TIUS	Truck Inventory and Use Survey
ULEV	Ultra Low Emission Vehicle
USDOC	U.S. Department of Commerce
USDOE	U.S. Department of Energy
USDOT	U.S. Department of Transportation

Acronym	Full Title or Description
USEPA	U.S. Environmental Protection Agency
TIUS	Truck Inventory and Use Survey
TMG	Traffic Monitoring Guide
ZEV	Zero Emission Vehicle

(This page left intentionally blank)

Annex B: Glossary of Related Vehicle Terminology

The following terms are used throughout this report and/or are commonly used in relation to electric and hybrid electric vehicles.

In some cases multiple definitions are found in the common literature. Where multiple defined terms exist, preference is given to federal or state publications and widely recognized consensus-developed codes and standards. Where these sources do not exist, widely recognized industry associations are utilized. In some cases multiple definitions of the same term are provided.

Alternative Fuel: The Energy Policy Act of 1992 defines alternative fuels as methanol, denatured ethanol, and other alcohol; mixtures containing 85 percent or more (but not less than 70 percent as determined by the Secretary of Energy by rule to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels. Includes compressed natural gas, liquid petroleum gas, hydrogen, coal-derived liquid fuels, fuels other than alcohols derived from biological materials, electricity, or any other fuel the Secretary of Energy determines by rule is substantially not petroleum and would yield substantial energy security and environmental benefits.[161]

Alternative Fuel: A motor vehicle fuel other than gasoline and diesel.[162]

Alternative Fuel Vehicle (AFV): As defined by the Energy Policy Act, any dedicated, flexible-fuel, or dual-fuel vehicle designed to operate on at least one alternative fuel.[163]

Battery: Electrochemical cells electrically connected in a series and/or parallel arrangement.[164]

Battery Efficiency: Net DC energy delivered on discharge, as a percentage of the total DC energy required to restore the initial state-of-charge. The efficiency value must include energy losses resulting from self-discharge, cell equalization, thermal loss compensation, and all battery-specific auxiliary equipment.[165]

Battery Electric Vehicle (BEV): An electric vehicle powered primarily by electricity stored in batteries. A BEV is not a hybrid electric vehicle.[166]

Dual Fuel Vehicle (DFV): Vehicle designed to operate on a combination of an alternative fuel and a conventional fuel. This includes (a) vehicles that use a mixture of gasoline or diesel and an alternative fuel in one fuel tank, commonly called flexible-fuel vehicles; and (b) vehicles capable of operating either on an alternative fuel, a conventional fuel, or both, simultaneously using two fuel systems. They are commonly called bi-fuel vehicles.[167]

Electric Car: An alternative fuel automobile that uses electric motors and motor controllers for propulsion, in place of more common propulsion methods such as the internal combustion engine.[168]

Electric Hybrid Vehicle (EHV): An electric vehicle that either (1) operates solely on electricity, but contains an internal combustion engine that generates additional electricity (series hybrid); or (2) contains an electric system and an internal combustion system and is capable of operating on either system (parallel hybrid). See also Hybrid Electric Vehicle.[169]

Electric Motor Vehicle (EMV): A motor vehicle powered by an electric motor that draws current from rechargeable storage batteries, fuel cells, photovoltaic arrays, or other sources of electric current.[170]

Electric Vehicle (EV): A vehicle powered by electricity, generally provided by batteries. EVs qualify as zero emission vehicles for emissions.[171]

Electric Vehicle (EV): A vehicle powered solely by energy stored in an electrochemical device.[172]

Electric Vehicle (EV): An automotive-type vehicle for highway use, such as passenger automobiles, buses, trucks, vans, and the like, primarily powered by an electric motor that draws current from a rechargeable storage battery, fuel cell, photovoltaic array, or other source of electric current. For the purpose of this article, electric motorcycles and similar type vehicles and off-road self-propelled electric vehicles, such as industrial trucks, hoists, lifts, transports, golf carts, airline ground support equipment, tractors, boats, and the like, are not included.[173]

EV Charging Station: The equipment required to condition and transfer energy from the constant frequency, constant voltage supply networks to the direct current, variable voltage EV traction battery bus for the purpose of charging the battery and/or operating vehicle electrical systems while connected.[174]

Fleet Vehicles:[175]

Private Fleet Vehicles: Ideally, a vehicle could be classified as a member of a fleet if it is:

a) operated in mass by a corporation or institution,
b) operated under unified control, or
c) used for non-personal activities.

However, the definition of a fleet is not consistent throughout the fleet industry. Some companies make a distinction between cars that were bought in bulk rather than singularly, or whether they are operated in bulk, as well as the minimum number of vehicles that constitute a fleet (i.e. 4 or 10).

Government Fleet Vehicles: Includes vehicles owned by all Federal, state, county, city, and metro units of government, including toll road operations.

Hybrid Electric Vehicle (HEV): A vehicle powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drive-train. See also Electric Hybrid Vehicle.[176]

Hybrid System: A system comprised of multiple power sources. These power sources may include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electrical production and distribution network systems. Energy storage systems, such as batteries, do not constitute a power source for the purpose of this definition.[177]

Inherently Low Emission Vehicle (ILEV): This is a federal standard only. Such a vehicle meets EPA CFV ILEV exhaust emission standards and produces very few or no evaporative emissions (5 grams or less per test without using auxiliary emission control devices). ILEVS are dedicated AFVs in most cases. Dual-fuel vehicles will be considered ILEVs only if both fuels meet the standard. ILEV credits can be banked in the Consolidated Metropolitan Statistical Area.[178]

Internal Combustion Engine (ICE): An engine that burns fuel inside a reaction chamber to create pressure inside the chamber that is converted into rotary motion. ICE engines are typically based on the Otto cycle, Atkinson cycle, or Wankel engine.[179]

Low Emission Vehicle (LEV): Any vehicle certified to the low emission standards which are set by the Federal government and/or the state of California.[180]

Light Duty Vehicle: Passenger cars and trucks with a gross vehicle weight rating of 8,500 or less.[181]

Medium Duty Vehicle: Typically, a vehicle with a gross vehicle weight rating of 8,500 to 14,000 lbs.[182]

Motor Vehicle (MV): A vehicle driven or drawn by mechanical power and manufactured primarily for use on public streets, roads, and highways, but does not include a vehicle operated only on a rail line. [183]

Motor Vehicle Equipment: Equipment that is part of a vehicle with the following characteristics:[184]

(a) Any system, part, or component of a motor vehicle as originally manufactured;
(b) Any similar part or component manufactured or sold for replacement or improvement of a system, part, or component, or as an accessory or addition to a motor vehicle; or
(c) Any device or an article or apparel (except medicine or eyeglasses prescribed by a licensed practitioner) that is not a system, part, or component of a motor vehicle and is manufactured, sold, delivered, offered, or intended to be used only to safeguard motor vehicles and highway users against risk of accident, injury, or death.

Motor Vehicle Safety: The performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle.[185]

Motor Vehicle Safety Standard: means a minimum standard for motor vehicle or motor vehicle equipment performance.[186]

Neighborhood Electric Vehicle: A four wheeled battery operated electric “low-speed vehicle”, with “low-speed vehicle” classified by U.S DOT as having a gross vehicle weight rating of less than 3,000 lbs. (1,400 kg) and a top speed of between 20 to 25 mph (32 to 40 km/h).[187]

Non-Road Vehicle: A vehicle that does not travel streets, roads, or highways. Such vehicles include construction vehicles, locomotives, forklifts, tractors, golf carts, and others. Also known as Off-Road Vehicle.[188]

Original Equipment Manufacturer (OEM): The original manufacturer of a vehicle or engine.[189]

Original Equipment Manufacturer (OEM): Any vehicle manufacturer or importer that is subject to DOT regulations and first introduces a vehicle for sale.[190]

Passenger Automobile: Any automobile (other than an automobile capable of off-highway operation) manufactured primarily for use in the transportation of not more than 10 individuals.[191]

Plug-in Hybrid Electric Vehicle (PHEV): Hybrid vehicles that can charge their batteries from an external source in the same fashion as electric vehicles.[192]

Super Ultra-Low-Emission Vehicle (SULEV): A vehicle that produces fewer exhaust emissions than do ultra-low-emission vehicles. ULEV credits can also be banked in the Consolidated Metropolitan Statistical Area.[193]

Transitional Low-Emission Vehicle (TLEV): Describes a vehicle that meets either EPA's CFV TLEV standards or CARB's California Low-Emission Vehicle Program TLEV standards. TLEVs produce fewer emissions than federal Tier 1 vehicles. TLEVs are eligible for the federal California Pilot Program but not eligible for the Clean-Fuel Fleet Program.[194]

Ultra Low Emission Vehicle (ULEV): Any vehicle certified to the ultra-low emission standards which are set by the Federal government and/or the state of California.[195]

U.S. Department of Energy (DOE): A department of the federal government, established by the Carter Administration in 1977, to consolidate energy-oriented programs and agencies. The DOE mission includes the coordination and management of energy conservation, supply, information dissemination, regulation, research, development and demonstration.[196]

U.S. Department of Transportation (DOT): A government agency whose mission is to ensure a fast, safe, efficient, accessible, and convenient transportation system that meets the national interests and enhances our quality of life.[197]

U.S. Environmental Protection Agency (EPA): A government agency, established in 1970, responsible for protecting the environment and public health. EPA seeks to reduce air, water, and land pollution and pollution from solid waste, radiation, pesticides, and toxic substances. EPA also controls emissions from motor vehicles, fuels, and fuel additives.[198]

Zero Emission Vehicle (ZEV): Any vehicle certified to the zero emission standards which are set by the Federal government and/or the state of California. These standards apply to the vehicle emissions only.[199]

(This page left intentionally blank)

Annex C: Overall Summary of Electric and Hybrid Electric Vehicles

This annex includes Table C-1, Overall Summary of Electric and Hybrid Electric Vehicles, which provides a summary of the available vehicles included within the scope of this project.[200,201,202]

This address vehicles that are sedans (two- or four-door passenger vehicle with at least four seats), coupes (two-seat passenger vehicle), SUV (sports utility vehicle), pickup, and van, but does not include trucks, buses, recreational, construction, farm and other similar vehicles. It also addresses EVs (electric vehicles), HEVs (hybrid electric vehicles), PHEVs (plug-in hybrid electric vehicles), and NEVs (neighborhood electric vehicles). With regard to model years, it includes discontinued vehicles that are no longer produced (since 1990), current vehicles in production, and concept prototypes.

Table C-1: Overall Summary of Electric and Hybrid Electric Vehicles[203,204,205]

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
AC Propulsion	**eBox**	Sedan	EV	2009	www.acpropulsion.com
AEV	**Kurrent**	Coupe	NEV	2009	www.getkurrent.com
Aptera	**2E**	Coupe	NEV	2009	www.aptera.com
Audi	**Q7 TDI Hybrid**	SUV	HEV	2010	www.audiusa.com
BB Buggies	**Bad Boy Buggy**	Coupe	NEV	2009	www.badboybuggies.com
BG Auto	**BG C100**	Coupe	NEV	2009	www.bgelectriccars.com
BMW	**ActiveHybrid 7**	Sedan	HEV	2010	www.bmwusa.com
	X6 Hybrid	SUV	HEV	2010	www.bmwusa.com
	City	Coupe	EV	2012	www.bmwusa.com
BYD	**E6**	Sedan	EV	Concept	www.byd.com
Cadillac	**Escalade Hybrid**	SUV	HEV	2009	www.cadillac.com
	Converj	Sedan	PHEV	Concept	www.cadillac.com
Chevrolet	**Malibu**	Sedan	HEV	2009	www.chevrolet.com/hybrid
	Silverado Hybrid	Pickup	HEV	2009	www.chevrolet.com/hybrid
	S-10 Electric	Pickup	EV	D/NLP	www.chevrolet.com/hybrid
	Tahoe Hybrid	SUV	HEV	2009	www.chevrolet.com/hybrid
	Volt	Sedan	PHEV	2010	www.chevrolet.com/hybrid
Chrysler	**Aspen Hybrid**	SUV	HEV	D/NLP	www.chrysler.com/en/2009/aspen/hybrid/
	Epic Electric Minivan	Van	EV	D/NLP	www.chrysler.com
Coda Auto	**Hafei Saibao 3 EV**	Sedan	EV	2010	www.codaautomotive.com
Commuter	**Tango T600**	Coupe	NEV	2009	www.commutercars.com
Daimler	**Smart For Two (ED)**	Coupe	EV	2010	www.smartusa.com
Dodge	**Ram Hybrid**	Pickup	HEV	2010	www.dodge.com
	Durango Hybrid	SUV	HEV	D/NLP	www.dodge.com
	Circuit	Coupe	EV	2011	www.dodge.com
	Grand Caravan Hybrid	Van	HEV	Concept	www.dodge.com
Dynasty	**IT**	Coupe	NEV	2009	www.itiselectric.com
Elbilen	**Buddy**	Coupe	NEV	2009	www.elbilnorge.no
FineMobile	**Twike**	Coupe	NEV	2009	www.twike.us
Fisker	**Karma**	Luxury	PHEV	2010	karma.fiskerautomotive.com

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
Flybo	**XFD-6000ZK**	Coupe	NEV	2009	www.flybo.cn
Ford	**Reflex**	Coupe	HEV	Concept	www.ford.com
	Electric Ranger	Pickup	EV	D/NLP	www.ford.com
	Fusion Hybrid	Sedan	HEV	2009	www.ford.com
	Escape Hybrid	SUV	HEV	2009	www.ford.com
	Escape Plug-in Hybrid	SUV	PHEV	2012	www.ford.com
	Focus EV	Sedan	EV	2011	www.ford.com
GEM	**GEM Car**	Coupe	NEV	2009	www.gemcar.com
GMC	**Sierra Hybrid**	Pickup	HEV	2009	www.gmc.com
	EV1	Sedan	EV	D/NLP	www.gmc.com
	Yukon Hybrid	SUV	HEV	2009	www.gmc.com
	Plug-in Crossover SUV	SUV	PHEV	2011	www.gmc.com
Honda	**CR-Z Hybrid**	Coupe	HEV	2010	www.honda.com
	Civic Hybrid	Sedan	HEV	2009	www.honda.com
	EV Plus	Sedan	EV	D/NLP	www.honda.com
	Insight	Sedan	HEV	2009	www.honda.com
	Fit Hybrid	Sedan	HEV	2010	www.honda.com
	Accord Hybrid	Sedan	HEV	D/NLP	www.honda.com
Hyundai	**Sonata Hybrid**	Sedan	HEV	2010	www.hyundaiusa.com
	Accent Hybrid	Sedan	HEV	2010	www.hyundaiusa.com
Infiniti	**M35 Hybrid**	Sedan	HEV	2011	www.infinitiusa.com
Keio	**Eliica**	Coupe	EV	Concept	www.eliica.com/English/
Lexus	**HS 250h**	Sedan	HEV	2009	www.lexus.com
	GS 450h	Sedan	HEV	2009	www.lexus.com
	LS 600h L	Sedan	HEV	2009	www.lexus.com
	RX 450h	SUV	HEV	2009	www.lexus.com
	RX 400h	SUV	HEV	2009	www.lexus.com
Lightning	**GT**	Coupe	EV	2010	www.lightningcarcompany.com
Mazda	**Tribute HEV**	SUV	HEV	2009	www.mazdausa.com
Mercedes	**S400 Blue Hybrid**	Sedan	HEV	2009	mbusa.com
	ML 450 Hybrid	SUV	HEV	2009	mbusa.com
	BlueZero	Sedan	EV	Concept	mbusa.com
Mercury	**Milan Hybrid**	Sedan	HEV	2009	www.mercuryvehicles.com
	Mariner Hybrid	SUV	HEV	2009	www.mercuryvehicles.com
	Meta One	Van	HEV	Concept	www.mercuryvehicles.com
Miles EV	**ZX 40S**	Sedan	EV	2009	www.milesev.com
Mini Cooper	**Mini E**	Sedan	EV	Concept	www.miniusa.com
Mitsubishi	**iMiEV**	Sedan	EV	Concept	www.mitsubishicars.com
Modec	**Box Van**	Van	EV	2009	www.modeczev.com
Mullen	**L1x-75**	Coupe	EV	Concept	www.mullenmotorco.com
Myers	**NmG**	Coupe	NEV	2009	www.myersmoters.com
Nissan	**Altima Hybrid**	Sedan	HEV	2009	www.nissanusa.com
	Altra	Sedan	EV	D/NLP	www.nissanusa.com
	Leaf	Sedan	EV	2010	www.nissanusa.com
Obvio	**828e**	Coupe	NEV	2009	www.obvio.ind.br
Phoenix	**Phoenix SUV**	SUV	EV	D/NLP	www.phoenixmotorcars.com
	Phoenix Pickup	Pickup	EV	D/NLP	www.phoenixmotorcars.com
Pininfarina	**Blue Car**	Sedan	EV	2010	www.pininfarina.com
Porsche	**Cayenne S Hybrid**	SUV	HEV	2010	www.porsche.com

Manufacturer	Model	Type	Class	Year	Web Link to Vehicle Information
Porteon	**EV**	Sedan	EV	Concept	www.porteon.net
Renault	**Fluence**	Coupe	EV	2011	www.renault.com
Reva	**NXR / NXG**	Coupe	NEV	2009	www.revaglobal.com
Saab	**BioPower Hybrid**	Sedan	HEV	Concept	www.saabusa.com
Saturn	**Aura**	Sedan	HEV	D/NLP	www.saturn.com
	Vue Hybrid	SUV	HEV	D/NLP	www.saturn.com
	Vue Green Line 2-Mode	SUV	HEV	D/NLP	www.saturn.com
Solectria	**Force**	Sedan	EV	D/NLP	www.azuredynamics.com
Smith	**Edison Panel Van**	Van	EV	2009	www.smithelectricvehicles.com
Spark Electric	**Comet**	Coupe	NEV	D/NLP	n/a
Subaru	**R1E**	Coupe	EV	Concept	www.subaru.com
Tesla	**Model S**	Coupe	EV	2011	www.teslamotors.com
	Roadster	Coupe	EV	2009	www.teslamotors.com
Think	**Th!nk City**	Coupe	EV	2009	www.think.no
Toyota	**Volta**	Coupe	HEV	Concept	www.toyota.com/hsd
	A-BAT Hybrid Truck	Pickup	HEV	Concept	www.toyota.com/hsd
	Prius	Sedan	HEV	2009	www.toyota.com/hsd
	Camry Hybrid	Sedan	HEV	2009	www.toyota.com/hsd
	Hybrid X	Sedan	HEV	Concept	www.toyota.com/hsd
	Highlander Hybrid	SUV	HEV	2009	www.toyota.com/hsd
	Prius Plug-in	Sedan	PHEV	2012	www.toyota.com/hsd
	RAV4 EV	SUV	EV	D/NLP	www.toyota.com/hsd
	FT-EV	Coupe	EV	Concept	www.toyota.com/hsd
	Sienna Hybrid	Van	HEV	Concept	www.toyota.com/hsd
Universal	**UEV Spyder**	Coupe	EV	D/NLP	n/a
Velozzi	**Supercar**	Coupe	EV	Concept	www.velozzi.org
Venture	**Pursu**	Coupe	NEV	2009	www.flytheroad.com
	VentureOne e50	Coupe	NEV	Concept	xprizecars.com/2008/06/venture-vehicles-ventureone.php
Venturi	**Fetish**	Coupe	EV	2009	www.venturifetish.fr
Volkswagen	**Touareg Hybrid**	SUV	HEV	2011	www.vw.com
Volvo	**3CCC**	Coupe	HEV	Concept	www.volvo.com
	V70 Plug-in Hybrid	Van	PHEV	2012	www.volvo.com
Wrightspeed	**X1**	Coupe	EV	Concept	www.wrightspeed.com
Zap	**Xebra**	Coupe	NEV	2009	www.zapworld.com
Zenn Motors	**CityZenn**	Coupe	NEV	2009	www.zenncars.com

(This page left intentionally blank)

Annex D: Example of Fire Service Standard Operating Guideline

This annex provides a specific example of a fire service Standard Operating Guideline (SOG) template for alternatively fueled vehicles, and in particular EVs and HEVs. The following information is provided courtesy of Ron Moore, McKinney Fire Dept, McKinney Texas:

Fire Department Standard Operating Guideline **# 000.0**
Operations Division
Issued 00-00-00
Revised 00-00-00 **Page 1 of 1**

EMERGENCY PROCEDURES for Gasoline-Electric HYBRID VEHICLES

I. Overview

This Operational guideline identifies recommended practices for Fire Department personnel to address when confronted with a gasoline-electric hybrid vehicle crash or fire incident.

It shall be the goal of _____________ Fire Department personnel arriving at the scene of a fire or crash-related incident involving a gasoline/electric hybrid vehicle to complete the seven (7) step hybrid vehicle "Lock Out – Tag Out" protocol. These essential actions should be accomplished as soon as practical after arrival and after completion of initial scene assessment and hazard control.

All responders should be aware of and fully understand the unique risks that personnel can potentially be exposed to when operating at a gasoline-electric hybrid vehicle incident.

Actions taken by responders should be in compliance with applicable manufacturer's Emergency Response Guide for that specific hybrid vehicle.

II. First-Arriving FD Apparatus

Tactical Procedures:

Benchmarks are listed, based upon the Lock Out – Tag Out protocol, for the first-arriving fire department units at a gasoline-electric hybrid vehicle emergency incident. These benchmarks include;

☐ Identify vehicle as hybrid . . .
☐ Stabilize vehicle. . .
☐ Access passenger compartment . . .
☐ Shift gear selector/ parking brake lever···
☐ Turn ignition OFF···
☐ Check that Hybrid vehicle dash indicator light/gauge is shut down···
☐ Disconnect/shutdown 12v battery . . .

III. Incident Command Benchmarks

The initial-arriving FD officer and/or the Incident Commander must assure that efforts to complete the seven (7) essential "Lock Out – Tag Out" benchmarks are initiated in addition to assigning personnel to accomplish actions necessary to effectively contain and control any additional challenge at the vehicle-related crash or fire incident.
Unless delegated to another responder, the initial company officer and/or Incident Commander shall serve as the Incident Safety Officer.

(This page left intentionally blank)

Annex E: Example of Fire Service Training Program on EVs and HEVs

This annex provides a specific example of a fire service training program addressing alternatively fueled vehicles, and in particular EVs and HEVs. While multiple programs are available from various qualified sources, the following summarizes one comprehensive program as an example. This is posted on the web site of the California State Fire Marshal's Office, and is available at the following URL: www.osfm.fire.ca.gov/training/alternativefuelvehicles.php

The information contained on their web site includes student manuals, lesson plans, student handouts, and instructor information. Interested parties should directly access their web site and download the applicable materials of interest. The following is the outline of this particular program:

I. Introduction
II. Internal Combustion
    Ethanol
    Biodiesel
    Natural Gas (CNG & LNG)
    Propane
    Hydrogen
III. Electric Vehicles
    Electric Vehicles Technology
    Hybrid Electric Vehicles
    Hybrid Electric Bus Technology
    Hydrogen Fuel Cell
IV. Emergency Response
    Alt-Fuel Vehicle Emergencies
    Alt-Fuel Vehicle Fires
    Extrication Safety and Organization
    Operational Safety

(This page left intentionally blank)

Annex F: Overview of Fire Service Training and Education

There are an estimated 1.1 million fire fighters in the United States today.[206] This estimate is based on a sample survey with a confidence level associated with each estimate, and does not include certain fire fighter constituency groups such as industrial fire departments and federal fire departments.

Approximately 75 percent of these fire fighters serve as volunteers with the remainder serving as career fire fighters. As expected, the more populated jurisdictions are protected primarily by career fire fighters while rural areas are protected primarily by volunteer fire fighters. Some fire departments are a mix of career and volunteer fire fighters in what are considered combination fire departments.

This section covers the preparation and process infrastructure utilized by fire fighters to perform their duties, with a focus on how they prepare for handling emergencies such as those involving electric and hybrid electric vehicles. A review is provided on what is typically included in fire service training and education programs, as well as an overview of fire service standard operating procedures and guidelines commonly used by fire fighters.

Defining the Profession of Fire Fighting

Fire fighters face a bewildering spectrum of possible emergency events. As a result they are generalists in their core knowledge and acquire specialized additional skills to handle certain duties.

Fire service personnel require skills that are already adequately learned and ready to be used before an emergency occurs. Beyond the obvious hazards associated with fireground operations, the duties of a fire fighter include the need for training on additional topics commonly shared with other professions. Examples include bio-hazards associated with handling of victims requiring emergency medical services, and transportation safety relating to the hazards of large mobile fire apparatus.

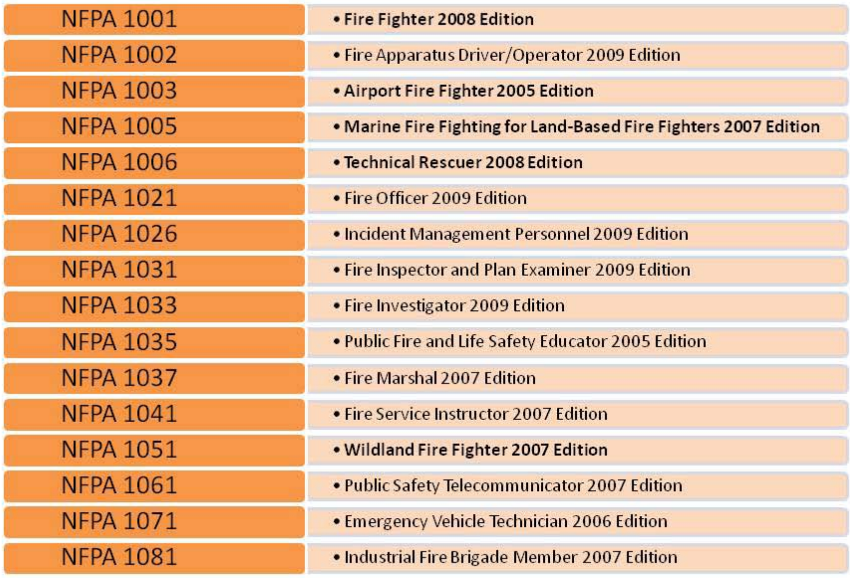
Fire service training and education is a critical part of the activities addressed by fire fighters. It is not uncommon for fire fighters to be in a situation where their own personal survival depends on this training and education, and they are continually subjected to learning on a wide range of important topics. For all topics of interest to fire service emergency responders, an on-going need exists for updated, accurate, consistent, readily understandable training information.

What distinguishes a fire fighter from someone who is not a fire fighter? Most obvious is an individual's formal relationship (e.g., employment or membership) with a recognized fire service organization. Equally important, however, is the individual's training and education that qualifies them to adequately perform the tasks expected of a fire fighter.

To be "*qualified by training and examination*" are critical defining characteristics for today's fire service. Among the various definitions of *fire fighter* in the common literature, the following reflects the baseline importance of qualification by training and examination:

> *"<u>Fire Fighter</u>: An individual qualified by training and examination to perform activities for the control and suppression of unwanted fires and related events"*[207]

Fire fighter professional qualifications are key to defining the profession of fire fighting. Standards that set baseline requirements have been subject to ongoing enhancements for decades (as exemplified by documents such as NFPA 1961, *Standard on Fire Hose*, which was first issued in 1898, or NFPA 1410, *Standard on Training for Initial Emergency Scene Operations*, first issued in 1966).[208,209]



NFPA 1001	• Fire Fighter 2008 Edition
NFPA 1002	• Fire Apparatus Driver/Operator 2009 Edition
NFPA 1003	• Airport Fire Fighter 2005 Edition
NFPA 1005	• Marine Fire Fighting for Land-Based Fire Fighters 2007 Edition
NFPA 1006	• Technical Rescuer 2008 Edition
NFPA 1021	• Fire Officer 2009 Edition
NFPA 1026	• Incident Management Personnel 2009 Edition
NFPA 1031	• Fire Inspector and Plan Examiner 2009 Edition
NFPA 1033	• Fire Investigator 2009 Edition
NFPA 1035	• Public Fire and Life Safety Educator 2005 Edition
NFPA 1037	• Fire Marshal 2007 Edition
NFPA 1041	• Fire Service Instructor 2007 Edition
NFPA 1051	• Wildland Fire Fighter 2007 Edition
NFPA 1061	• Public Safety Telecommunicator 2007 Edition
NFPA 1071	• Emergency Vehicle Technician 2006 Edition
NFPA 1081	• Industrial Fire Brigade Member 2007 Edition

Figure F-1: Types of Fire Fighters, According to NFPA Professional Qualification Standards

Of particular interest for addressing fire fighter performance is the set of 16 NFPA standards addressing fire fighter professional qualifications. These documents are summarized in Figure F-1, and they clarify fire fighting disciplines and establish required levels of knowledge that can be used for training and other purposes.

The fire service operates as a quasi-military type organization, with the need for potentially large numbers of fire service members to be quickly deployed to handle complicated emergencies. Further, efficient and effective handling of the event is necessary to minimize danger to life and property, which means that there is normally very little time to implement mitigating action.

Table F-1: Examples of Fire Fighting Disciplines and Training Levels[210]

FIRE FIGHTING DISCIPLINE	EXAMPLES OF LEVELS	NFPA STANDARD
Airport Fire Fighter		1003
Driver/Operator	Pumper; Aerial, Tiller; ARFF; Mobile Water Supply; Wildland	1002
EMS HazMat	I, II	473
Fire Department Safety Officer	Health/Safety Officer; Incident Safety Officer; ISO-Fire Suppression; ISO – EMS Operations; ISO – HazMat Operations; ; ISO – Special Operations	1521
Fire Fighter	I; II	1001
Fire Inspector	I; II; III; Plans Examiner	1031
Fire Investigator		1033
Fire Officer	I; II; III; IV	1021
Fire Service Instructor	I; II; III	1041
Hazardous Materials	Awareness; Operations; Technician; Incident Commander; Branch Safety Officer; Private Sector Specialist A, B, C; Tech w/Tank Car Specialty, Tech w/Cargo Tank Specialty; Tech w/Intermodal Tank Specialty; Tech w/ Flammable Gases Bulk Storage Specialty; Tech w/ Flammable Liquids Bulk Storage Specialty	472
Industrial Fire Brigade	Incipient; Advanced Exterior; Interior Structural; Advanced Structural; Leader	1081
Marine Fire Fighter	I, II	1005
Public Fire & Life Safety Educator	I; II; III; Public Information Officer; Juvenile Firesetter Intervention Specialist	1035
Public Safety Telecommunicator	I; II	1061
Rescue Technician	Rope; Confined Space; Trench; Structural Collapse; Surface Water; Vehicle & Machinery	1006
Wildland Fire Fighter	I, II	1051

As a result, multiple specialized fire fighting disciplines have evolved to address certain tasks and duties as defined by the level of training and education they receive. Table F-1 summarizes examples of fire fighting disciplines and the standardized levels to which fire fighters can be qualified.

The last several years has seen a more widespread use of these standards, partly because five (NFPA 1000, 1001, 1002, 1006, and 1021) are among the 27 NFPA standards adopted as national preparedness standards by the U.S. Department of Homeland Security.[211] Each year DHS distributes millions of dollars in aid through their "Assistance to Firefighters Grant" (AFG) to U.S. fire departments, which is administered by the U.S. Federal Emergency Management

Agency (FEMA). A prerequisite for applying for this support is conformance to these DHS national preparedness standards. The 19,791 applications requesting more than $3.1 billion in AFG grants in 2009 indicate the level of activity in this DHS/FEMA program.[212]

Training versus Education

In today's fire service the terms training and education are sometime used synonymously; however, they have different meanings.[213] While both refer to the transfer of information from a body of knowledge to a recipient, each has a different focus on the purpose and details of the information transfer methodology.

Training is an exercise in focused learning, and refers to the exchange of specific information intended to enhance the proficiency of a particular skill. An example of training is a fire fighter class that teaches the skills necessary for certification at the "Awareness Level" for a hazardous materials incident. Training is more applicable to specific emergency events such as handling a motor vehicle accident.

In contrast, education refers to broad-based learning, with the intent of providing a foundation of general knowledge that supports efficient analytical techniques for effective problem solving. An example is a college degree in business administration, which will provide a fire service officer with the skill set needed to manage a large city fire department.

In general, the technical content for fire service training is well-established and addresses a wide range of topics faced by fire fighters. Much of this is captured in the mainstream literature and national standards (e.g., NFPA standards) addressing a wide range of fire fighting tasks, equipment, and other fire service detail. Some of this information has been developed and refined in various arenas for decades.

Specifically, multiple sources of training materials are available that extensively address useful content on the topic of motor vehicle emergencies. These training materials can be readily adapted and used directly by members of the fire service and other emergency responders. A wide assortment of broadly developed training materials and guidance materials are available that provide support. This includes, for example, the training manuals provided by the International Fire Service Training Association (since 1932), fire service training materials provided by Jones and Bartlett Publishers, and various books and publications provided through Delmar Learning.[214,215,216]

The Fire Service Training Infrastructure

Fire departments are the basic organizations used by fire fighters to deliver their services. These can range from a small volunteer fire department in rural areas, to large fire departments with all career personnel protecting a major metropolitan city. Training will also depend on the specific hazards within the protected jurisdiction, such as the difference between an industrial district and a bedroom community.

Fire departments, regardless of their size or type, have two distinct sources for their training needs: (1) training programs that originate and operate internally within the organization, and (2) those that originate and operate externally. Figure F-2 illustrates the two basic sources of training information and materials for the fire service.

Figure F-2: Types of Training Sources

The extent of internal training sources depends on the available resources of the particular fire department, and as a result, these internal sources tend to be more extensive and sophisticated for larger fire departments (e.g., large city or county fire departments). These larger fire departments generally have their own dedicated training divisions as well as training facilities (i.e., training academy), and are able to effectively handle recruit training and in-service training. Specialized training may be offered for specific duties such as fire apparatus operators, incident commanders, or safety officers. They may also offer specialized courses like those intended for duties beyond the front-line emergency responders, such as fire investigators, fire prevention and inspection personnel (i.e., permitting officials), and public fire and life safety educators.

Multiple external sources of training information and materials are available from a number of sources. These are available to directly support the many fire departments (and especially smaller departments) with limited resources for training. In addition, they also help to supplement and support larger fire departments with their own training departments, and while doing so promote general consistency throughout the fire service. In some cases, regional training centers fulfill internal training needs despite their external characteristics, and these may be operated at the county or state level, or simply by multiple fire service organizations joining together for this purpose. Figure F-3 provides an overview of fire service training, from the perspective of the external sources that directly influence today's fire service training.

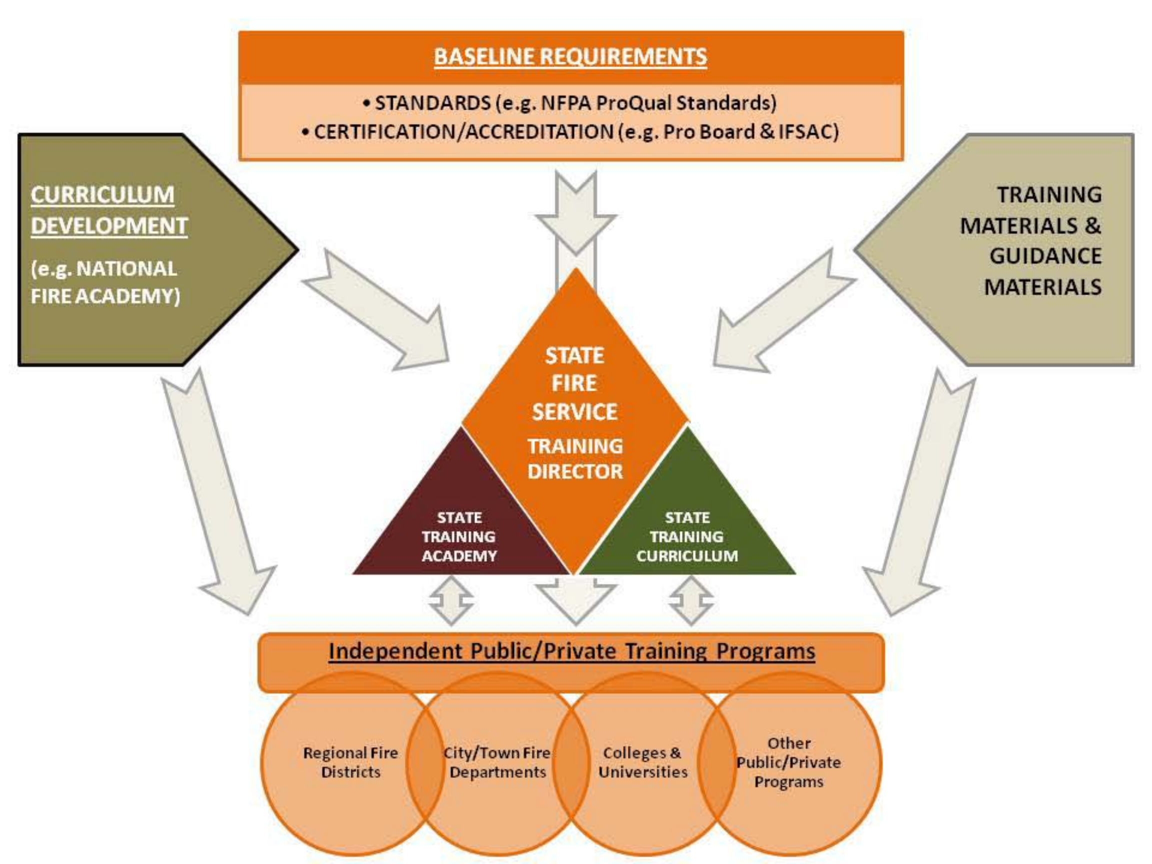


Figure F-3: Overview of the External Sources of Fire Service Training

State governments are a key external resource for fire departments, and many states have designated an official agency to provide statewide training for fire and emergency personnel. Similarly but at a higher level, the federal government provides important support through the National Fire Academy and other resources. Depending on the legislative and funding arrangements in a particular state or region, certain colleges and universities may serve as centers for fire service training, with or without the involvement of their respective state agency. Supporting these training programs is a group of national fire service organizations and private training service organizations that provide valuable components for the fire service training infrastructure.

State training agencies and state training directors are central players in the fire service training infrastructure. Training directors sometimes report to the state fire marshal in each state, and many states operate a statewide training academy. In addition, many also coordinate the training materials and curriculums used throughout the state. In some states fire departments within the state are required to mandatorily use this information and material, and in others they can voluntarily utilize it as they deem appropriate.

Independent public and private training programs that exist within the state often work in coordination with state training programs. These may include the fire service training activities of regional fire districts, large city fire departments, colleges and universities, and other public or private fire service training programs. The relationships among these entities vary significantly from state to state. For example, one state may not have a dedicated state fire training academy and instead have multiple separate but similar training programs throughout the state in conjunction with the state community college system. Elsewhere there may be a state training academy, but the large city fire departments use their own training resources and do not participate in the state programs.

On a national level, several key programs, activities and initiatives feed into the multitude of fire service training activities found at the local and state levels. An example is the National Fire Academy that assists state and local organizations with curriculum development and the national promotion of technical training content. Important baseline requirements are set by the applicable standards that manage the training content and provide a level of agreement on the applicable professional qualifications. These baseline requirements are effectively implemented through accreditation and certification processes.

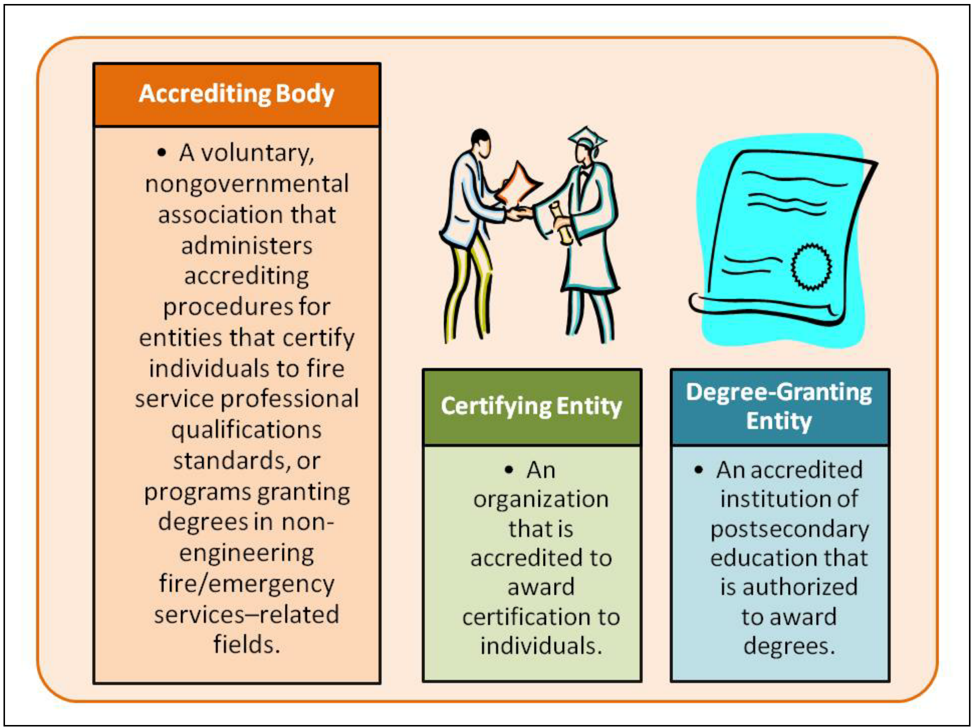
Administering Qualifications for the Fire Service

Fire fighting as a profession has been recognized for centuries among various civilizations. It was not until more recently, however, that its professional status has become more distinctly defined, with the development of standardized baseline requirements and the implementation and quality assurance process that supports the use of these requirements.

Starting in 1974, NFPA's professional qualifications standards began to appear, becoming increasingly used by state agencies responsible for fire service training in the years since. The use of national standards for fire fighter professional qualifications is a concept that political leaders have been able to widely support, and the appearance of these documents has independently coincided with a general rise in funding and recognition for state fire service training programs.[217]

As a result, most states utilize these standards as the defining measure of professional qualifications for fire fighters. However, certification programs in many states are voluntary, and states often do not have mandatory minimum qualifications requirements for fire service personnel.

The baseline requirements included in national standards provide a foundation for fire fighter professional qualifications, but how these are applied is equally important. To achieve consistent implementation, the processes of accreditation, certification, and degree granting have evolved. The organizations that administer these training and educational programs are known as accrediting bodies, certifying entities, and degree-granting entities, respectively. These are summarized in Figure F-4, which provides an overview of the entities that accredit, certify, and grant degrees.



Accrediting Body

- A voluntary, nongovernmental association that administers accrediting procedures for entities that certify individuals to fire service professional qualifications standards, or programs granting degrees in non-engineering fire/emergency services–related fields.

Certifying Entity

- An organization that is accredited to award certification to individuals.

Degree-Granting Entity

- An accredited institution of postsecondary education that is authorized to award degrees.

Figure F-4: Overview of Entities that Accredit, Certify, and Grant Degrees[218]

As further explanation, accreditation refers to enabling oversight (within a recognized framework that measures and assures quality implementation), bestowed upon another organization. Once accredited, that organization will in turn provide certifications and/or grants degrees to individuals. The following are definitions for accredit, certification, and degree:[219]

> *“Accredit. To give official authorization to or to approve a process or procedure to recognize as conforming to specific criteria, and to recognize an entity as maintaining standards appropriate to the provision of its services.”*[220]
>
> *“Certification. An authoritative attestment; specifically, the issuance of a document that states that an individual has demonstrated the knowledge and skills necessary to function in a particular fire service professional field.”*[221]
>
> *“Degree. A formal recognition of completion of a prescribed program of study at the postsecondary level.”*[222]

Annex G: Attendees at Fire Service Workshop on Electric Drive and Hybrid Electric Vehicles

The following is a summary of the subject matter experts that attended and participated in the “Fire Service Workshop on Electric Drive and Hybrid Electric Vehicles”, held in Detroit, Michigan on 16 March 2010.

Table G-1, Attendees at Fire Service Workshop on Electric Drive and Hybrid Electric Vehicles

Last Name	First Name	Organization	City, State	
Abraham	Harry	NFPA	Quincy, MA	1
Baker	George	OnStar Public Policy	Warren, MI	2
Burke	George	Madison Are Technical College (NAFTC Rep)	Madison, WI	3
Croushore	Tim	Allegany Power (CMP-12 Chair)	Greensburg, PA	4
Dalton	James	Chicago Fire Dept.	Chicago, IL	5
Earley	Mark	NFPA	Quincy, MA	6
Emery	Jason	Waterbury FD (Emerg Training Solutions)	Harwinton, CT	7
Grant	Casey	FPRF/NFPA	Quincy, MA	8
Hittel	Michael	General Motors (CMP-12; SAE Hybrid TC)	Warren, MI	9
Hollenstain	Tom	State Farm, ATR - Vehicle Research Facility	Bloomington, IL	10
Kerber	Stephen	Underwriters Laboratories	Northbrook, IL	11
Kissel	Gery	General Motors (CMP-12; SAE Hybrid TC)	Warren, MI	12
Klock	Andrew	NFPA	Quincy, MA	13
Kreis	Timothy	Phoenix Fire Dept.	Phoenix, AZ	14
Minter	Jeffrey	Madison Area Technical College (NAFTC rep)	Madison, WI	15
Moore	Ron	McKinney TX FD	McKinney, TX	16
Orlando	Ron	General Motors	Warren, MI	17
Paiss	Matt	San Jose Fire Dept. (NGLB Training Group)	San Jose, CA	18
Peterson	Eric	FPRF/NFPA	Quincy, MA	19
Roper	Ed	SC State Training Academy, (NAFTD)	Columbia, SC	20
Sanfilippo	Tony	MI State Fire Marshal’s Office	Lansing, MI	21
Sawyer	Steve	NFPA	Quincy, MA	22
Schultz	Keith	General Motors	Warren, MI	23
Shaw	Ron	Extrication.Com	Plymouth MA	24
Stroud	Matt	MGS Tech	Shoreline, WA	25
Van de Velde	Marc	Global Asset Protection Services LLC	Frankfurt, Germany	26
Varone	Curt	NFPA	Quincy, MA	27
Willse	Pete	XL Global Asset Protection Services	Hartford, CT	28
Wimer	Dan	DR&W Enterprises	Rochester, NY	29