Plug In Electric Vehicles In Smart Grids Integration Techniques Power Systems

Hybridization and Multi-objective Optimization of Plug-in Hybrid Electric Vehicles

Electric Vehicle Primer

Modern Hybrid Electric Vehicles provides vital guidance to help a new generation of engineers master the principles of and further advance hybrid vehicle technology. The authors address purely electric, hybrid electric, plug-in hybrid electric, hybrid hydraulic, fuel cell, and off-road hybrid vehicle systems. They focus on the power and propulsion systems for these vehicles, including issues related to power and energy management. They concentrate on material that is not readily available in other hybrid electric vehicle (HEV) books such as design examples for hybrid vehicles, and cover new developments in the field including electronic CVT, plug-in hybrid, and new power converters and controls. Covers hybrid vs. pure electric, HEV system architecture (including plug-in and hydraulic), off-road and other industrial utility vehicles, non-ground-vehicle applications like ships, locomotives, aircrafts, system reliability, EMC, storage technologies, vehicular power and energy management, diagnostics and prognostics, and electromechanical vibration issues. Contains core fundamentals and principles of modern hybrid vehicles at component level and system level. Provides graduate students and field engineers with a text suitable for classroom teaching or self-study.

Hybrid and Plug-In Electric Vehicles (Brochure).

There has never been a Hybrid Electric Vehicles Guide like this. It contains 110 answers, much more than you can imagine; comprehensive answers and extensive details and references, with insights that have never before been offered in print. Get the information you need--fast! This all-embracing guide offers a thorough view of key knowledge and detailed insight. This Guide introduces what you want to know about Hybrid Electric Vehicles. A quick look inside of some of the subjects covered: Hyundai Motor Company - Electric vehicles, Hydrogen vehicle - Plug-in hybrids, Lithium polymer battery - Electric vehicles, Plug-in electric vehicles in the UK - Purchase incentives, Plug-in electric car, Electric vehicle warning sounds - Regulations, All-electric car - Regenerative braking, Alternative fuel car - Hybrid, BYD Auto - Products, Motor vehicle, Hybrid electric vehicles in the United States - Markets and sales, Ford Motor Corporation - Hybrid electric vehicles, Plug-in hybrid electric vehicle, Henney Kilowatt - Designers and developers, Petroleum fuel - Alternatives to petroleum-based vehicle fuels, Plug-in electric vehicles in the UK - Cost-effectiveness of carbon reductions, Government incentives for plug-in electric vehicles - Japan, Hydrogen (car) - Plug-in hybrids, Battery swapping, Electric vehicle warning sounds - Enhanced Vehicle Acoustics, Electric vehicle - Efficiency, Plug-in electric vehicle - Air pollution and greenhouse gas emissions, Plug-in electric vehicle fire incidents, The Hype about Hydrogen - Critical reception, Environmental technology - Alternative and clean power, Plug-in hybrid - Greenhouse gas emissions, Green technologies - Alternative and clean power, Altairnano - Battery technology, High-occupancy vehicle lane - Qualifying vehicles, Honda Insight - United States, and much more

Plug-in Electric Vehicles Market

Integrating Plug-in Electric Vehicles Into the Electric Power System

"Explains the current landscape for plug-in electrics and implications for national security, the environment, and the economy. Discusses what can and should be done by the U.S. government to advance the role of plug-in electric vehicles"--Provided by publisher.

Knowledge Base for the Market in Electric Vehicles and Plug-in Hybrids
Plug In Electric Vehicles in Smart Grids

This authoritative new resource provides a comprehensive introduction to plug-in electric vehicles (PEVs), including critical discussions on energy storage and converter technology. The architecture and models for sustainable charging infrastructures and capacity planning of small scale fast charging stations are presented. This book considers PEVs as mobile storage units and explains how PEVs can provide services to the grid. Enabling technologies are explored, including energy storage, converter, and charger technologies for home and park charging. The adoption of EV is discussed and examples are given from the individual battery level to the city level. This book provides guidance on how to build and design sustainable transportation systems. Optimal arrival rates, optimal service rates, facility location problems, load balancing, and demand forecasts are covered in this book. Time-saving MATLAB code and background tables are included in this resource to help engineers with their projects in the field.

San Diego Regional Plug-in Electric Vehicle (PEV) Readiness Plan

In this book, theoretical basis and design guidelines for electric vehicles have been emphasized chapter by chapter with valuable contribution of many researchers who work on both technical and regulatory sides of the field. Multidisciplinary research results from electrical engineering, chemical engineering and mechanical engineering were examined and merged together to make this book a guide for industry, academia and policy maker.

Planning and Operation of Plug-In Electric Vehicles

Plug-in Hybrid Electric Vehicles and Energy Use

Well-to-Wheels Energy Efficiency Analysis and Optimal Energy Management Strategy for Varying Electric Vehicle Operational Characteristics Ebrahim Saeidi Dehaghani Transition to electric vehicles (EVs) is already under way. EVs were demonstrated to be the most fuel economic and emission free among other propulsion technologies. Electric and plug-in hybrid electric vehicles (EVs/PHEVs) can have a large impact on greenhouse gases (GHGs) reduction, increase in fuel economy and higher fuel efficiency. This thesis seeks to investigate the Well-to-Wheels (WTW) energy efficiency analysis of Electric Vehicles (EVs) in Canada. The main idea behind this research work is to analyze step by step energy efficiency, which is one of the key factors for EVs technology acceptance. Penetration of battery electric and more electric vehicles (BEVs/MEVs) into vehicle fleet, affects load demand as well as electricity market. Smart charging of EVs can remove a lot of stress from electricity grid. Effect of home charging of EVs/PHEVs on electricity demand in the province of Quebec was analyzed. More recently, EVs have been looked at as distributed sources of energy, whereby they could back up the power grid during critical high demand periods. With the help of an on-board battery pack, EVs can act as distributed generators and feedback energy to the AC grid. However, efficiency of energy conversion could become an issue in this power flow. Hence, in this thesis stage-by-stage efficiency of vehicle-to-grid (V2G) power flow was evaluated. In addition, feasibility of using EVs in international islanding to sustain the local grid in the event of an emergency was analyzed.

Overcoming Barriers to Electric-Vehicle Deployment

The nation has compelling reasons to reduce its consumption of oil and emissions of carbon dioxide. Plug-in hybrid electric vehicles (PHEVs) promise to contribute to both goals by allowing some miles to be driven on electricity drawn from the grid, with an internal combustion engine that kicks in when the batteries are discharged. However, while battery technology has made great strides in recent years, batteries are still very expensive. Transitions to Alternative Transportation Technologies—Plug-in Hybrid Electric Vehicles builds on a 2008 National Research Council report on hydrogen fuel cell vehicles. The present volume reviews the current and projected technology status of PHEVs; considers the factors that will affect how rapidly PHEVs could enter the marketplace, including the interface with the electric transmission and distribution system; determines a maximum practical penetration rate for PHEVs consistent with the time frame and factors considered in the 2008 Hydrogen report; and incorporates PHEVs into the models used in the hydrogen study to estimate the costs and impacts on petroleum consumption and carbon dioxide emissions.

Plug In Electric Vehicles in Smart Grids

Plug-in hybrid electric vehicles (PHEVs) are being developed around the world, with much work aiming to optimise engine and battery for efficient operation, both during discharge and when grid electricity is available for recharging. However, the general expectation has been that the grid will not be greatly affected by the use of PHEVs because the recharging will occur during off-peak hours, or the number of vehicles will grow slowly enough so that capacity planning will respond adequately. This expectation does not consider that drivers will control the timing of recharging, and their inclination will be to plug in when convenient, rather than when utilities would prefer. It is important to understand the ramifications of adding load from PHEVs onto the grid. This book analyses the potential impacts of PHEVs on electricity demand, supply, generation structure, prices and associated emission levels.

Plug-in Electric Vehicles

This study focused on Joint Base Lewis McChord (JBLM), which is located in Washington State. Task 1 consisted of the non-tactical fleet of vehicles at JBLM to begin the review of vehicle mission assignments and the types of vehicles in service. In Task 2, daily operational characteristics of select vehicles were identified and vehicle movements were recorded in data loggers in order to characterize the vehicles' missions. In Task 3, the results of the data analysis and observations were provided. Individual observations of the selected vehicles provided the basis for recommendations related to PEV adoption (i.e., whether a battery electric vehicle or plug-in hybrid electric vehicle [collectively referred to as PEVs] can fulfill the mission requirements), as well as the basis for recommendations related to placement of PEV charging infrastructure. This report focuses on an implementation plan for the near-term adoption of PEVs into the JBLM fleet.

Smart Charging of Plug-in Electric Vehicles in Distribution Systems Considering Uncertainties
This book highlights the latest advancements in the planning and operation of plug-in electric vehicles (PEVs). In-depth, the book presents essential planning and operation techniques to manage the PEV fleet and handle the related uncertainties associated with the drivers’ behavior. Several viewpoints are presented in the book, ranging from the local distribution companies to generation companies to the aggregators. Problems such as parking lot allocation and charging management are investigated, taking into consideration the technical, geographical, and social aspects in a smart grid infrastructure. Discusses the technical specifications of electrical distribution and generation systems; Models drivers’ behavior from the sociology and economic points of view; Considers the real geographical characteristics of area and driving routes in San Francisco, CA; US; Chicago, IL; US; and Tehran, Iran.

**Electric Vehicles**

Rising gas prices create a pain in our pocketbooks with every visit to the gas pump. What can you do to stop your dependence on big oil and imported fuel? Energy and EV Secrets not only spells out how your oil dependence is undermining your individual bank accounts; it shows how imported oil is impacting the security of our troops, the health of our economy, and the creation of good jobs. The first half of the book will make it crystal clear that changing these conditions is a pressing priority. That priority will only increase as the global competition for oil intensifies over the coming decades with direct impacts on your gas prices. The book provides reliable facts and figures from national and international sources to create readily understandable graphics. These graphics and the accompanying descriptions provide a clear picture of the global oil challenges and the need to save energy. When you see these facts, it will show you the way to move forward. The EV Solution The book goes on to show how to stop the oil dependence by making the transition to the electric vehicle (EV) solution. The EV solution saves energy and involves cutting your fuel costs to pay for the electric cars and e-bikes. It can stop the need for importing oil and free you from the tyranny of gas prices. It takes all of the wrong minded ideas about electric vehicles, e-bikes and plug-in hybrids like the Volt and puts those ideas to rest. You will learn how the old ideas and outdated excuses about EVs are all part of the mindset that keeps us addicted to oil. Energy and EV Secrets makes it clear that you can free yourself from the age of the internal combustion engine – the ICE age. It will help you to develop the EV Mindset to become oil free and to cut the drain of money that goes with rising gas prices.

**Energy and EV Secrets**

* Describes the basics of electric-drive vehicles, including hybrid electric vehicles, plug-in hybrid electric vehicles, all-electric vehicles, and the various charging options.

**The Global Rise of the Modern Plug-In Electric Vehicle**

Plug-in hybrid electric vehicles (PHEVs), which share the characteristics of both a conventional HEV and an all-electric vehicle, rely on large storage batteries. Therefore, the characteristics and hybridization of the PHEV battery with the engine and electric motor play an important role in the design and potential adoption of PHEVs. In this research, a multi-objective optimization approach is applied to compare the operational performance of Toyota Prius PHEV20 (PHEV for 20 miles of all electric range) based on fuel economy, operating cost, and greenhouse gas emissions for 4480 combinations (20 batteries, 14 motors, and 16 engines). Powertrain System Analysis Toolkit software package automated with the Pareto Set Pursuing multi-objective optimization method is used for this purpose on two different drive cycles. It was found that 1) battery, motor, and engine work collectively in defining an optimal hybridization scheme; and 2) the optimal hybridization scheme varies with drive cycles.

**Implementation Approach for Plug-in Electric Vehicles at Joint Base Lewis McChord, Task 4**

This book covers the recent research advancements in the area of charging strategies that can be employed to accommodate the anticipated high deployment of Plug-in Electric Vehicles (PEVs) in smart grids. Recent literature has focused on various potential issues of uncoordinated charging of PEVs and methods of overcoming such challenges. After an introduction to charging coordination paradigms of PEVs, this book will present various ways the coordinated control can be accomplished. These innovative approaches include hierarchical coordinated control, model predictive control, optimal control strategies to minimize load variance, smart PEV load management based on load forecasting, integrating renewable energy sources such as photovoltaic arrays to supplement grid power, using wireless communication networks to coordinate the charging load of a smart grid and using market price of electricity and customers payment to coordinate the charging load. Hence, this book proposes many new strategies proposed recently by the researchers around the world to address the issues related to coordination of charging load of PEVs in a future smart grid.

**Plug-In Hybrid Electric Vehicles (Presentation)**

This book offers a comprehensive yet accessible snapshot of the latest consumer research on the adoption and use of electric vehicles. It discusses the importance of developing a better understanding of consumer behavior in relation to electric vehicles, and the advantages that can be gained from the growing number of electric vehicle users, who can now be studied directly. In turn, it systematically analyzes the leading markets for electric vehicles in North America, Europe and Asia. Bringing together the experience and expertise of authoritative researchers and practicing professionals, the book shares a wide range of empirical data obtained at the national level and summarizes the general lessons learned. The last part of the book discusses policy-relevant insights, forecasts the future evolution of the field in terms of methods and data availability, and addresses several key questions that policymakers and other stakeholders are currently facing.

**Overcoming Barriers to Deployment of Plug-in Electric Vehicles**

The electric vehicle offers many promises-increasing U.S. energy security by reducing petroleum dependence, contributing to climate-change initiatives by decreasing greenhouse gas (GHG) emissions, stimulating long-term economic growth through the development of new technologies and industries, and improving public health by improving local air quality. There are, however, substantial technical, social, and economic barriers to widespread adoption of electric vehicles, including vehicle cost, small driving range, long charging times, and the need for a charging infrastructure. In addition, people are unfamiliar with electric vehicles, are uncertain about their costs and benefits, and have diverse needs that current electric vehicles might not meet. Although a person might derive some personal benefits from ownership, the costs of achieving the social benefits, such as reduced GHG emissions, are borne largely by the people who purchase the vehicles. Given the recognized barriers to electric-vehicle adoption, Congress asked the Department of Energy (DOE) to commission a study by the National Academies to address market barriers that are slowing the purchase of electric vehicles and hindering the deployment of supporting
infrastructure. As a result of the request, the National Research Council (NRC)-a part of the National Academies-appointed the Committee on Overcoming Barriers to Electric-Vehicle Deployment. This committee documented their findings in two reports—a short interim report focused on near-term options, and a final comprehensive report. Overcoming Barriers to Electric-Vehicle Deployment fulfills the request for the short interim report that addresses specifically the following issues: infrastructure needs for electric vehicles, barriers to deploying the infrastructure, and possible roles of the federal government in overcoming the barriers. This report also includes an initial discussion of the pros and cons of the possible roles. This interim report does not address the committee's full statement of task and does not offer any recommendations because the committee is still in its early stages of data-gathering. The committee will continue to gather and review information and conduct analyses through late spring 2014 and will issue its final report in late summer 2014. Overcoming Barriers to Electric-Vehicle Deployment focuses on the light-duty vehicle sector in the United States and restricts its discussion of electric vehicles to plug-in electric vehicles (PEVs), which include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The common feature of these vehicles is that their batteries are charged by being plugged into the electric grid. BEVs differ from PHEVs because they operate solely on electricity stored in a battery (that is, there is no other power source); PHEVs have internal combustion engines that can supplement the electric power train. Although this report considers PEVs generally, the committee recognizes that there are fundamental differences between PHEVs and BEVs.

Modeling of Plug-in Electric Vehicles Interactions with a Sustainable Community Grid in the Azores

Who’s Driving Electric Cars

Price-driven Charging of Plug-in Electric Vehicles in the Smart Grid

Distribution feeders and equipment are designed to serve peak loads, and in the absence of Plug-in Electric Vehicle (PEV) loads, day-ahead dispatch of feeders is typically performed by optimizing feeder controls for forecasted load profiles. However, due to climate change concerns, the market share of PEVs is expected to increase, and consequently, utilities expect an increase in demand due to these loads charging from the grid. Uncontrolled charging of PEVs may lead to new peaks in distribution feeders, which would require expensive infrastructure and equipment upgrades. Furthermore, PEV loads will represent new sources of uncertainty, temporal and spatial, which will pose a challenge for the centralized control and optimal operation of the grid. In practice, these uncertainties arise as a result of variability in factors such as the number of PEVs connected to the grid for charging, the arrival and departure times of PEVs, and the initial battery State-of-Charge (SoC). Hence, the integration of PEVs into the existing distribution system, without significant infrastructure upgrades, will be possible only through smart charging of these loads, while properly accounting for these uncertainties. The elasticity of PEVs provides a level of flexibility that can be used by utilities or Local Distribution Companies (LDC) to ensure efficient feeder operation, while providing fair and efficient charging to PEV customers. This thesis presents a novel two-step approach for the fair charging of PEVs in a primary distribution feeder, accounting for the uncertainty associated with PEVs, considering the perspectives of both the LDC and the PEV customer.

Determining the Optimal Subsidy for Plug-in Electric Vehicles in the United States by County

Plug-in Electric Vehicles Integrating Fluctuating Renewable Electricity

Climate change, urban air quality, and dependency on crude oil are important societal challenges. In the transportation sector especially, clean and energy efficient technologies must be developed. Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) have gained a growing interest in the vehicle industry. Nowadays, the commercialization of EVs and PHEVs has been possible in different applications (i.e., light duty, medium duty, and heavy duty vehicles) thanks to the advances in energy storage systems, power electronics converters (including DC/DC converters, DC/AC inverters, and battery charging systems), electric machines, and energy efficient power flow control strategies. This book is based on the Special Issue of the journal Applied Sciences on “Plug-In Hybrid Electric Vehicles (PHEVs)”. This collection of research articles includes topics such as novel propulsion systems, emerging power electronics and their control algorithms, emerging electric machines and control techniques, energy storage systems, including BMS, and efficient energy management strategies for hybrid propulsion, vehicle-to-grid (V2G), vehicle-to-home (V2H), grid-to-vehicle (G2V) technologies, and wireless power transfer (WPT) systems.

Hybrid Electric Vehicles

Plug in Electric Vehicles in Smart Grids

Transitions to Alternative Transportation Technologies—Plug-in Hybrid Electric Vehicles

Provides an overview on the current status, long-term prospects, and key challenges in the development of plug-in hybrid electric vehicle technology.

Plug-in Electric Vehicle Grid Integration
Hybrid Electric Vehicles 110 Success Secrets - 110 Most Asked Questions on Hybrid Electric Vehicles - What You Need to Know

Analysis of Integration of Plug-in Hybrid Electric Vehicles in the Distribution Grid

Climate change, urban air quality, and dependency on crude oil are important societal challenges. In the transportation sector especially, clean and energy efficient technologies must be developed. Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) have gained a growing interest in the vehicle industry. Nowadays, the commercialization of EVs and PHEVs has been possible in different applications (i.e., light duty, medium duty, and heavy duty vehicles) thanks to the advances in energy storage systems, power electronics converters (including DC/DC converters, DC/AC inverters, and battery charging systems), electric machines, and energy efficient power flow control strategies. This book is based on the Special Issue of the journal Applied Sciences on "Plug-In Hybrid Electric Vehicles (PHEVs)". This collection of research articles includes topics such as novel propulsion systems, emerging power electronics and their control algorithms, emerging electric machines and control techniques, energy storage systems, including BMS, and efficient energy management strategies for hybrid propulsion, vehicle-to-grid (V2G), vehicle-to-home (V2H), grid-to-vehicle (G2V) technologies, and wireless power transfer (WPT) systems.

Special section on plug-in hybrid electric vehicles

In the past few years, interest in plug-in electric vehicles (PEVs) has grown. Advances in battery and other technologies, new federal standards for carbon dioxide emissions and fuel economy, state zero-emission-vehicle requirements, and the current administration's goal of putting millions of alternative-fuel vehicles on the road have all highlighted PEVs as a transportation alternative. Consumers are also beginning to recognize the advantages of PEVs over conventional vehicles, such as lower operating costs, smoother operation, and better acceleration; the ability to fuel up at home; and zero tailpipe emissions when the vehicle operates solely on its battery. There are, however, barriers to PEV deployment, including the vehicle cost, the short all-electric driving range, the long battery charging time, uncertainties about battery life, the few choices of vehicle models, and the need for a charging infrastructure to support PEVs. What should industry do to improve the performance of PEVs and make them more attractive to consumers? At the request of Congress, Overcoming Barriers to Deployment of Plug-in Electric Vehicles identifies barriers to the introduction of electric vehicles and recommends ways to mitigate these barriers. This report examines the characteristics and capabilities of electric vehicle technologies, such as cost, performance, range, safety, and durability, and assesses how these factors might create barriers to widespread deployment. Overcoming Barriers to Deployment of Plug-in Electric Vehicles provides an overview of the current status of PEVs and makes recommendations to spur the industry and increase the attractiveness of this promising technology for consumers. Through consideration of consumer behaviors, tax incentives, business models, incentive programs, and infrastructure needs, this book studies the state of the industry and makes recommendations to further its development and acceptance.

On Optimization of Plug-in Hybrid Electric Vehicles

Electric Cars

This book focuses on the design of decentralized optimization methods applied to charging strategies for large-scale PEVs in electrical power systems. It studies several classes of charging coordination problems in large-scale PEVs by considering the distinct characteristics of PEV populations and electrical power systems, and subsequently designs decentralized methods based on distinct optimization schemes — such as non-cooperative games, mean-field games, and auction games — to achieve optimal/nearly optimal charging strategies. In closing, several performance aspects of the proposed algorithms, such as their convergence, computational complexity and optimality etc., are rigorously verified and demonstrated in numerical simulations. Given its scope, the book will benefit researchers, engineers, and graduate students in the fields of optimization, game theory, auction games, electrical power systems, etc., and help them design decentralized methods to implement optimal charging strategies in large-scale PEVs.

Plug-in Hybrid Electric Vehicle (PHEV)

Compilation of Utility Commission Initiatives Related to Plug-in Electric Vehicles and Electric Vehicle Supply Equipment

This book highlights the cutting-edge research on energy management within smart grids with significant deployment of Plug-in Electric Vehicles (PEV). These vehicles not only can be a significant electrical power consumer during Grid to Vehicle (G2V) charging mode, they can also be smartly utilized as a controlled source of electrical power when they are used in Vehicle to Grid (V2G) operating mode. Electricity Price, Time of Use Tariffs, Quality of Service, Social Welfare as well as electrical parameters of the network are all different criteria considered by the researchers when developing energy management techniques for PEVs. Risk-averse stochastic energy hub management, maximizing profits in ancillary service markets, power market bidding strategies for fleets of PEVs, energy management of PEVs in the presence of renewable energy in distribution lines or microgrids and loss minimization in distribution networks based on smart coordination approaches using real time energy prices are some of the attractive and novel topics explored in this book. It will be an excellent reference for graduate students, researchers and industry professionals who are interested in getting a snapshot view of today’s latest research on applying various smart energy management strategies for smart grids with high penetration of PEVs.

Plug-in Hybrid Electric Vehicle (PHEV)
We may be standing on the precipice of a revolution in propulsion not seen since the internal combustion engine replaced the horse and buggy. The anticipated proliferation of electric cars will influence the daily lives of motorists, the economies of different countries and regions, urban air quality and global climate change. If you want to understand how quickly the transition is likely to occur, and the factors that will influence the predictions of the pace of the transition, this book will be an illuminating read.

Electric Vehicles

The market for electrified light-duty vehicles (also called passenger vehicles; including passenger cars, pickup trucks, SUVs, and minivans) has grown since the 1990s. During this decade, the first contemporary hybrid-electric vehicle debuted on the global market, followed by the introduction of other types of electric vehicles (EVs). By 2018, electric vehicles made up 4.2% of the 16.9 million new light-duty vehicles sold in the United States that year. Meanwhile, charging infrastructure grew in response to rising electric vehicle ownership, increasing from 3,394 charging stations in 2011 to 78,301 in 2019. However, many locations have sparse or no public charging infrastructure. Electric motors and traction battery packs-most commonly made up of lithium-ion battery cells-set EVs apart from internal combustion engine vehicles (ICEVs). The battery pack provides power to the motor that drives the vehicle. At times, the motor acts as a generator, sending electricity back to the battery. The broad categories of EVs can be identified by whether they have an internal combustion engine (i.e., hybrid vehicles) and whether the battery pack can be charged by external electricity (i.e., plug-in electric vehicles). The numerous vehicle technologies further determine characteristics such as fuel economy rating, driving range, and greenhouse gas emissions. EVs can be separated into three broad categories: * Hybrid-electric vehicles (HEVs): The internal combustion engine primarily powers the wheels. The battery pack and electric motor provide supplemental power. * Plug-in hybrid-electric vehicles (PHEVs): The battery pack can be charged by an external source of electricity. Depending on the model, primary power to the wheels may be supplied by the battery pack and electric motor, the internal combustion engine, or a combination. * All-electric vehicles (AEVs; also called battery-electric vehicles or BEVs): The battery pack must be charged via an external source of electricity. The battery pack and electric motor power the wheels. Current technology offers three levels of charging for plug-in EVs. Level 1 and Level 2 are currently the most widely accessible with standardized vehicle connectors and charge ports that can be set up for at-home charging. Level 3 (also called DC fast charging) offers the fastest charging rates on the market but is not available for at-home installation due to high voltage. Vehicle connectors and corresponding charge ports for Level 3 are also not standardized, with three different systems currently in use by different vehicle manufacturers. Some research has raised concerns regarding the potential impact of fast charging on battery performance, resulting in technology development aimed at addressing potential capacity loss and decreased charging cycles. As an emergent technology area, EVs present a number of issues for consideration. The fuel sources used to generate the electricity to charge PHEVs and AEVs are a major factor in determining EV greenhouse gas emissions relative to ICEVs. Per-mile EV emissions vary geographically and with the time of day and year that charging takes place. Growing demand for lithium-ion batteries also shifts the material requirements of the vehicle market from fuels for combustion to minerals and other materials for battery production. A growing EV market may encourage new strategies around the supply and refining of raw materials, ability to manufacture batteries, and end-of-life management for batteries that are no longer suitable for use in vehicles. Support for EV deployment stems from, among other things, federal and state policies establishing manufacturing rebates, tax credits for purchases, funding for research and development, and standards for fuel economy and emissions. These policies include the Plug-In Electric Vehicle Tax Credit, and the coordinated Corporate Average Fuel Economy (CAFE) standards and emissions standards for vehicles.