# Table of Contents

## Letter from the Electrification Coalition
- Page 5

## Executive Summary
- Page 8

## PRIMER
- Electrification of the Transportation Sector
  - Overview
  - The Case for Electrification
  - A Growth Sector for Jobs
  - Market Outlook
  - Expanding the Demand Side
  - Total Cost of Ownership Approach to Acquisition
  - Route Predictability
  - High Vehicle Utilization Rates
  - Use of Central Parking Facilities
  - Importance of Maintenance and Service Costs
  - Lower Electricity Rates
  - Alternative Business Models
  - Corporate Sustainability Initiatives
  - Part One

## PART ONE
- The Case For Fleets
  - Overview
  - Fleet Demographics
  - Advantages of Fleet Operators
  - Total Cost of Ownership Approach to Acquisition
  - Route Predictability
  - High Vehicle Utilization Rates
  - Use of Central Parking Facilities
  - Importance of Maintenance and Service Costs
  - Lower Electricity Rates
  - Alternative Business Models
  - Corporate Sustainability Initiatives

## PART TWO
- Fleet Challenges
  - Overview
  - Fleet Challenges
  - Technology Costs
  - Capital Expenditures vs. Operating Expense
  - Battery Residual Value
  - Fleet Infrastructure Issues
  - Utility Impact of Dense Charge Networks
  - Market Perception

## PART THREE
- Identifying Fleet Opportunities
  - Overview
  - Modeling Assumptions
  - Key Findings
  - Case Studies
  - Market Outlook
  - Expanding the Demand Side
  - Part Two

## PART FOUR
- Policy Recommendations
  - Overview
  - Other Policies
  - Conclusion

## Appendix A: Top 50 Commercial Fleets
- Page 142

## Appendix B: Available Vehicle Matrix
- Page 144

## Key to Terms
- Page 148

## Acknowledgements
- Page 150
OUR MISSION

The Electrification Coalition is dedicated to reducing America’s dependence on oil through the electrification of transportation. Our primary mission is to promote government action to facilitate deployment of electric vehicles on a mass scale. The Coalition serves as a dedicated rallying point for an array of electrification allies and works to disseminate informed, detailed policy research and analysis.

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LETTER FROM THE ELECTRIFICATION COALITION

In November 2009, the Electrification Coalition released the Electrification Roadmap, a comprehensive policy framework analyzing the state of the electric drive vehicle industry and the barriers to achieving higher rates of penetration in America’s light-duty vehicle fleet. The goal of the Roadmap was ambitious: to transform the U.S. light-duty ground transportation system from one that is oil-dependent to one powered almost entirely by electricity, enhancing U.S. economic prosperity and safeguarding national security. The report proposed an ambitious federal initiative to establish ‘electrification ecosystems’ in a number of American cities. Electrification ecosystems—also known as deployment communities—were designed to move grid-enabled electric vehicles (GEVs) past early adopters and into mainstream consumer markets.

The Electrification Roadmap envisioned a competitive selection process managed by the Department of Energy (DOE). To compete, applicant cities and communities would need to demonstrate that they had made significant progress toward establishing the regulatory environment in which GEVs would thrive. The most competitive applications would demonstrate the support of a broad range of public and private stakeholders, including utilities, utility regulators, large local employers, vehicle and charger OEMs, and state and local governments. The winning communities would be eligible for targeted, amplified, temporary subsidies for consumers, infrastructure providers, and utilities. The program was proposed to advance in two phases and expire in 2018.
Deployment communities were designed to build critical momentum in the cost and learning curves that otherwise are likely to slow the early advancement of the GEV market. Without such an approach, electric vehicles and plug-in hybrid electric vehicles are likely to be relegated to niche status for many years, purchased only by environmentalists and technological enthusiasts, in numbers far too small to meaningfully enhance national or economic security. In April 2010, DOE updated its energy-related scenarios to reflect the expected impact of the American Recovery and Reinvestment Act on the entire energy economy. Despite specific GEV-related subsidies included in the legislation, DOE estimated that by 2035, there will be only 5.1 million EVs and PHVs on the road out of nearly 300 million light-duty vehicles in the United States, representing less than 1.7 percent of the total vehicle parc. These numbers are far lower than what is possible within the appropriate policy framework. They are also far less than what is urgently necessary to radically transform the transportation sector of the economy to enhance national and economic security. Therefore, the Electrification Roadmap established as a goal the deployment of 14 million grid-enabled light-duty vehicles in the United States by 2020 and more than 120 million by 2030, a far more ambitious and transformative target. Ultimately, the Electrification Roadmap targeted a substantial shift in transportation energy use, such that 75 percent of light-duty vehicle miles traveled would be electric miles by 2040. The Electrification Roadmap also outlined potentially zero-cost programs to support development of a secondary battery market, allowing the first GEV consumers to feel confident that used large-format lithium-ion batteries would have resale value.

Finally, the Electrification Roadmap identified the areas in which utilities would need support and flexibility to manage the integration of GEVs into the electric power grid. Deployment communities were designed to target those regions in which time-of-use pricing and other regulatory support was available to incentivize consumers to charge batteries during on-peak hours. Tax credits for utility upgrades were proposed, and utility regulators were encouraged to allow utilities to include certain physical and IT upgrades to the distribution network in their rate base. This network of mutually reinforcing policies was designed to expand the customer base for grid-enabled vehicles in an accelerated, but carefully planned, manner. The increased economies of scale, learning by doing, and demonstration value of the deployment community approach would benefit pragmatic consumers, industry participants, and the nation as whole.

Expanding the Market for GEVs: Fleet Vehicles

The Electrification Roadmap focused on the light-duty vehicle parcc because it is the single largest homogenous component of the transportation sector, with 230 million vehicles alone that account for 40 percent of U.S. daily oil demand. Addressing the energy mix in this segment will ultimately be critical for improving national and economic security. Yet, the highway transportation system and the transportation economy are multifaceted and diverse, and it is possible that other segments besides light-duty passenger vehicles in the consumer market could be strong candidates for electrification and electric drive technology. Those segments may relate to the operational and economic challenges and benefits of electrification differently, and solutions to the technical and cost barriers to adoption might be more forthcoming. In particular, the nation’s fleet vehicles stand out as possessing unique characteristics that could make them clear beneficiaries of electric drive technology. With more than 16.3 million vehicles in operation in 2009, the nation’s fleets likely possess enough capacity to drive initial ramp-up scale in the battery industry and OEM supply chains. More important, the operational norms of certain fleet segments may allow them to rapidly mount the most difficult challenges facing electrification in the passenger market. Perhaps most significantly, fleet owners may be more willing than individual consumers to focus on total cost of vehicle ownership as opposed to upfront costs. This approach offers advantages that are economic, including lower battery costs and lower operating and maintenance costs over time.

Fleet owners may also benefit from operational norms such as centralized refueling, high vehicle utilization, and predictable routing. In fact, coupled together, centralized refueling and highly predictable routing could allow fleet operators to right-size battery requirements, avoiding the expenditure that many private consumers in the passenger vehicle market will be making on extra battery capacity that will rarely be fully utilized. Fleet operators also tend to take advantage of commercial and industrial electricity rates, which are significantly lower than those paid by residential consumers. The prominence of vehicle leasing and management entities in the passenger industry may also facilitate the development of innovative business models that bundle capital expenses with fuel and operating savings in order to make the decisions to electrify more transparent and accessible for fleet operators.

Of course, there are significant challenges that could make fleet operators hesitant to adopt electric drive vehicles. Fears about the reliability of the technology and the ability of electric drive vehicles to meet fleet mission requirements are perhaps the most important issues. Fleet operators are extremely unlikely to sacrifice overall mission for reduced transportation costs. Electric drive technologies must, therefore, meet two discrete criteria in order to be attractive to fleet operators: they must save money and allow fleet vehicles drivers to do their job effectively.

Fleet electrification should not be an end in itself. By driving volume in battery and OEM supply chains, providing practical business experience with both private and public charging infrastructure, and demonstrating the reliability of electric drive vehicles to consumers throughout the United States, electrified fleet vehicles would provide substantial spillover benefits to the broader consumer market. In that sense, fleet electrification represents an additional, practical, near-term strategy for facilitating the transformation of the U.S. transportation system and improving American energy security.
EXECUTIVE SUMMARY

Between 2003 and 2009, the global oil market witnessed its most significant period of volatility in nearly a generation. After relentlessly increasing for five years, oil prices spiked to historical highs of more than $147 per barrel in July 2008.¹ Not by coincidence, the home mortgage and global financial crises erupted just a few months later, plunging the U.S. economy into its most severe recession since World War Two. After retreating to less than $40 per barrel in early 2009, oil prices have now averaged more than $70 per barrel throughout 2010.²

Highly volatile oil prices have been the most persistent structural risk to the U.S. economy for decades. The boom and bust cycle of oil prices that has been in place since 2003—and a number of other times since 1970—contributes to a high degree of uncertainty throughout the economy, resulting in reduced economic activity, higher unemployment, and expansion of public debt. When global oil market dynamics generate price shocks, the result has often been a recession followed by heavy government spending.

The macroeconomic significance of oil price shocks is a function of the prominent role of oil in the U.S. economy. Petroleum accounts for nearly 40 percent of U.S. primary energy needs, more than any other fuel.³ In 2008, as oil prices reached inflation-adjusted all-time highs, American consumers and businesses spent more than $900 billion on retail petroleum-based fuels—6.4 percent of GDP.⁴ While 2008 represents an exceptional year, economy-wide spending on petroleum fuels has averaged more than 5 percent of GDP since 2005, and household spending on gasoline has exceeded 10 percent of median income in some regions of the United States.⁵

More than 70 percent of the oil we use is for transportation fuels.⁶ At approximately 14 million barrels per day, the U.S. transport sector alone consumes more oil than any other national economy in the world.⁷ Highway transportation—passenger vehicles, freight trucks, and buses—accounts for the largest share, more than 11 million barrels per day.⁸ With no substitutes available at scale, petroleum provides 94 percent of the energy used in transportation.⁹ In short, oil powers the mobility that is central to American prosperity and the American way of life.

This excessive reliance on a single fuel to power a key component of our economy has left the United States hostage to a global oil market that is likely to become increasingly volatile. Rising demand for mobility in emerging market economies is driving a steady increase in global oil consumption, despite efficiency improvements in advanced economies. Between 2008 and 2030, increased oil consumption in the transportation sectors of China, India, and the Middle East region is expected to account for 70 percent of the total 15 million barrel per day increase in global oil consumption.¹⁰ Bourgeoning middle classes and higher standards of living in these regions will place consistent pressure on global oil suppliers to expand capacity. In the meantime, resource nationalism, political instability, and insufficient upstream investment in many oil producing regions are continuing to constrain growth in oil supplies. While oil markets are certainly well supplied today, perhaps the

2 Id.
4 DOE, Office of Energy Efficiency and Renewable Energy (EERE), Transportation Energy Data Book 2010, Table 1.14.
5 DOE, AER 2009, Table 3.1.c through 3.1.d.
6 DOE, AER 2009, Table 3.1.a through 3.1.b.
7 DOE, AER 2009, Table 7.1.5 through 7.1.9.
8 DOE, Office of Energy Efficiency and Renewable Energy (EERE), Transportation Energy Data Book 2010, Table 1.14.
9 DOE, AER 2009, Table 2.1c.
most significant risk to a full global economic recovery is that expanded economic activity will lead to higher oil demand and reduced capacity margins, propelling oil prices back toward 2008 levels.

The United States has the technological and economic power to disentangle itself from this situation. While improvements in efficiency and the targeted deployment of alternative fuels can—and should—play a role in reducing the role of oil in the U.S. economy, a more transformational possibility is within reach. Specifically, U.S. and global automakers have invested heavily in producing vehicles powered by electricity from the grid. These vehicles have the ability to fundamentally transform our transportation sector, moving from cars and trucks that depend on costly oil-based fuels to an integrated system that powers our mobility with domestically-generated electricity.

Electrified transportation has clear advantages over the current petroleum-based system. Electricity represents a diverse, domestic, stable, fundamentally scalable energy supply whose fuel inputs are almost completely free of oil. High penetration rates of grid-enabled vehicles (GEVs)—vehicles propelled in whole or in part by electricity drawn from the grid and stored onboard in a battery—could radically minimize the importance of oil to the United States, strengthening our economy, improving national security, and providing much-needed flexibility to our foreign policy. Simultaneously, such a system would clear a path to dramatically reduced economy-wide emissions of greenhouse gases.

In the process, electrified transportation would stem the flow of U.S. wealth abroad to pay for imported oil, which currently accounts for more than 50 percent of America’s trade deficit.10 Dollars sent abroad to pay for oil represent a significant wealth transfer; in contrast, dollars spent at home to invest in power generation, transmission, and distribution will help to generate economic activity and employment in the United States. And because the battery industry tends to locate near demand centers, a large market for GEVs in the United States should drive increased hiring in the manufacture of advanced batteries and their components.

The first wave of new GEVs is expected in U.S. markets in December 2010 and early 2011. General Motors, Nissan Motor Company, and Ford Motor Company will be among the first automakers to introduce fully electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) to American consumers. Total North American deployment of alternative fuels can—and should—play a role in reducing the role of oil in the U.S. economy, a more transformational possibility is within reach. Specifically, U.S. and global automakers have invested heavily in producing vehicles powered by electricity from the grid. These vehicles have the ability to fundamentally transform our transportation sector, moving from cars and trucks that depend on costly oil-based fuels to an integrated system that powers our mobility with domestically-generated electricity.

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To date, policymakers and industry participants have focused their efforts on expanding the market for GEVs among personal-use passenger vehicles. This approach is clearly justified by the role that passenger vehicles play in U.S. oil consumption. Personal use cars and light-duty trucks alone account for 40 percent of total U.S. oil demand.

However, in order to support development of the electric drive vehicle industry and to help drive down industry costs for consumers, alternative vehicle markets could be important in the near term. The early development of the electric drive vehicle and battery industries would benefit from a diverse customer base that can help drive critical volumes, particularly in the period between 2010 and 2015, when charging infrastructure and consumer acceptance issues will constrain development of the passenger market. Specifically, commercial and government fleet applications stand out as highly viable market segments based on the operational needs of the vehicles and the economic factors that drive vehicle acquisition processes.

Based on total cost of ownership modeling conducted for this report, commercial and government fleets could contribute substantial volume commitments in the early development phases of the GEV market. The economic attractiveness of electric drive vehicles in certain applications—coupled with operational enhancements and targeted use of public policy levers—could drive grid-enabled vehicle penetration in U.S. commercial and government fleets to as much as 7 percent of new acquisitions by 2015. In aggregate, the market for EVs and PHEVs in fleet applications could lead to cumulative unit commitments of more than 200,000 EVs and PHEVs between 2011 and 2015.
There were more than 16 million public and private fleet vehicles on the road in the United States in 2009. While the size of individual fleets varies significantly, the top 50 fleet operators together manage more than half a million cars. These vehicles perform a variety of missions for federal, state, and local government, and for companies that are familiar to nearly all Americans. They are delivery vehicles, utility and telecommunications service trucks, pharmaceutical sales vehicles, urban delivery vans, and others.

The concentration of buying power associated with fleet operators and fleet management companies represents a significant opportunity to assist the early development of the electric drive vehicle industry. Moreover, fleets tend to possess a handful of important characteristics that may make them more likely than typical consumers to take on the potential risks of electric drive vehicles.

High Vehicle Utilization Rates: Fleet vehicles typically have higher utilization rates than consumer vehicles. The result may be that fleet operators can quickly recoup the higher upfront costs of electric drive vehicles.

Use of Central Parking Facilities: Fleets that make use of central parking depots may be able to avoid dependence on public charging infrastructure and benefit from economies of scale in single-point installation of multiple chargers in individual facilities.

Importance of Maintenance and Service Costs: Particularly in fleet applications that operate vehicles for longer periods of time or into high mileage ranges, the low maintenance costs of electric drive vehicles will represent a substantial cost savings.

Lower Electricity Rates: The electricity rates paid by commercial and industrial consumers—those most likely to make use of fleet vehicles and central refueling—are often significantly less than those paid by residential consumers. The fuel cost per mile traveled is one of the key economic factors differentiating plug-in electric drive vehicles from other technologies.

Alternative Business Models: Based on their access to capital and larger purchasing power, fleet managers may benefit from alternative business models that can help facilitate adoption of electric drive technology.

Corporate Sustainability: Commercial and government enterprises may also consider electric drive vehicles in the context of corporate sustainability initiatives. EVs can help meet reduced emissions and petroleum consumption goals.

While fleet operators do possess a number of important qualities that could facilitate their adoption of electric vehicles, they will also face challenges. Some of the basic cost and technology hurdles for individual consumers will also be problematic for fleets, though fleets may be better equipped to deal with them. In addition, fleet electrification may come with its own set of unique challenges that can be addressed through a combination of careful planning and public policy support.

Fleet Infrastructure Issues: Even for fleets that centrally park, the cost of installing charging infrastructure may be significant. With Level II chargers costing averaging $4,000 per unit, the cost of installing enough chargers to support a fleet of several dozen EVs or PHEVs could be challenging. Level III charging may offer faster charge times and reduced unit requirements, but costs are still too high.

Utility Impact of Dense Charge Networks: Bringing a fleet of EVs or PHEVs into a small charging space will bring an unusually high burden to those areas and may require upgrades to local utility distribution networks. In particular, transformers serving charging facilities may be insufficiently robust to support the simultaneous charging of multiple vehicles. Utilities will need access to information and regulatory support to deal with these and other issues.

Market Perceptions: Perhaps the most critical challenge affecting fleet adoption of electric drive technology will be fleet adopters’ impressions about the technology and its ability to meet their operational needs. Even when a compelling economic case exists, fleet operators will need to be confident that the vehicle can accomplish the mission.

### Fleet Challenges

**Technology Costs:** Battery costs associated with the first commercially available electric drive vehicles will result in a substantial overall cost premium. Current battery technology is descending the cost curve as volumes increase, but under some fleet applications, it may be difficult to realize a return on investment in a reasonable time period. Ultimately, fleet operators may be more willing than personal-use consumers to consider multi-year paybacks, but they will still want to see returns relatively quickly.

**Capital Expenditures vs. Operating Expense:** There is typically intense competition for capital within a given company or institution. The high capital cost requirements of today’s electric drive vehicles, particularly in applications heavier than a passenger automobile, will prove challenging for many fleet operators. Even extremely large businesses may be unwilling to tie up capital to support substantial volumes of electric drive vehicles.

**Battery Residual Value:** Today, estimating the residual value of used large-format automotive batteries is an educated guess at best. Early test data suggests that lithium-ion batteries may still possess 70 to 80 percent of their ability to store energy when they are no longer fit for automotive use. But this needs to be borne out by practical experience.
In order to better understand the business, economic, and cost-saving opportunities presented by electrification of vehicle fleets, an economic model was developed for the Fleet Electrification Roadmap. The model compares the total cost of ownership (TCO) of sample vehicles by vehicle weight class and industry segment for a given acquisition year. Technologies considered were ICE, HEV, PHEV-40, and EV-100. The analysis considers vehicle TCO in three cases: a base case, an optimization case, and a combined optimization plus policy incentives case.

**Base Case:** The base case assumes operators purchase vehicles being offered in the market today at current specifications. Operators make no behavioral changes to reduce cost. Public policy is not considered in the base case. Operators do not benefit from existing or future subsidies.

**Optimized Case:** The optimized case assumes fleet operators can purchase vehicles that fit their needs and that they will use them in the manner that most efficiently lowers cost. Battery right-sizing and extended ownership periods are examples of optimized use. Operators do not benefit from existing or future subsidies.

**Policy Case:** The policy case builds on the optimization case, adding existing federal government incentives for light-duty vehicles and assuming additional subsidies not currently in law for medium- and heavy-duty trucks.

The model analysis suggests that electric drive vehicles are cost competitive in a number of fleet applications today—even when assuming no access to government subsidies and no change in purchasing or usage patterns. In fact, traditional hybrids are a cost-effective replacement for internal combustion engine vehicles by 2012 in most of the segments where driving distance exceeds 20,000 miles per year. This is a result of the relatively small incremental investment for an HEV compared to an ICE vehicle. In the base case, GEVs begin to emerge as the most cost effective solution between 2015 and 2018 as battery costs begin to fall below $400/kWh.

The cost effectiveness timeline for each of the electric drive vehicle technologies is improved by optimizing operations and vehicle characteristics for a number of fleet applications. In particular, two options stand out: optimizing the GEV ownership duration to coincide with the battery life; and right-sizing the EV batteries to meet the needs of low mileage fleet applications. These two actions taken by fleet operators would advance the time required for PHEVs and EVs to become the most cost effective solutions by approximately one year in a number of segments. Figure E6 presents the competitiveness timelines for the optimized case.

Finally, when current and potential future government incentives are considered, the cross-over point for GEV cost parity is reached within the next two to three years in all of the commercial segments. The incentives assumed for this analysis include $7,500 federal tax credits applied for GEV passenger car and class 1-2 trucks; $15,000 tax credits applied to class 3 medium-duty trucks; $20,000 tax credits applied to class 4-5 medium-duty trucks; and $25,000 tax credits applied to class 6-7 heavy-duty trucks. (For the full credits were assumed to be available through 2015, after which they were ramped down annually, reaching zero in 2020.)

In all cases, this analysis implies a progression in cost competitiveness from ICE, though HEV, to PHEV-40 and EV-100. Fleet owner behavior and public policy can have a dramatic impact on the rate of that progression, but rising fuel costs coupled with falling electric drive component costs suggest that PHEVs and EVs will increase in competitiveness over time in nearly all fleet segments.

**FIGURE E5** Lowest TCO Drivetrain Technology by Year and Segment – Base

**FIGURE E6** Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized

**FIGURE E7** Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized + Government Incentives
The Electrification Coalition has identified a suite of policies to facilitate the adoption of grid-enabled vehicles by fleet operators. These policies are intended to narrowly address the specific obstacles to electric drive vehicle adoption that the Coalition identified in the Electrification Roadmap, adjusted to account for the specific challenges faced by fleets. These policies, therefore, are intended to be consistent with the policies outlined in the Electrification Roadmap, and to support the adoption of electric drive vehicles in managed fleets. They are not intended as a substitute for policies promoted by the original Electrification Roadmap.

**Fleet Microsystems**

In many cases, fleets function as a microcosm of a transportation ecosystem that could manage many—if not all—of the key elements of an electrification ecosystem/deployment community. For example, a fleet might consist of numerous vehicles that operate together in a confined geographical space. This is certainly true for mid-sized fleets that operate as part of geographically constrained organizations such as a utility or city government. For national fleets, such as parcel delivery and telecommunication fleets, at least a subset of their vehicles frequently serve individual regions or urban areas. In addition, centrally refueled fleets provide refueling systems for their vehicles at a home base or bases, allowing them to closely manage the cost and reliability of energy infrastructure access. Finally, in the case of a fleet attached to large commercial, industrial, or government entity, the fleet operator (or its parent) will likely have a direct relationship with the local utility.

The various types of financial support that would be available to consumers and infrastructure providers in deployment communities should be available to fleet operators, who may serve as a kind of electrification micro-ecosystem—or fleet microsystem. Like electrification ecosystems, GEV fleet microsystems offer the opportunity to accelerate the adoption of grid-enabled vehicles by promoting scale and cost reductions in battery and vehicle production. While fleets ultimately represent a smaller market than general personal use autos, the obstacles to their adoption of electric drive technology are also smaller in some cases, and can be addressed by targeted public policies.

**Fleet Policy Recommendations**

- Expand the tax credits for light-duty grid-enabled vehicles purchased in deployment communities to include private sector fleets.
- Create tax credits for medium- and heavy-duty grid-enabled vehicles deployed in fleets with greater than 10 vehicles in operation.
- Create clean renewable energy bonds for fleet vehicle charging infrastructure, and make municipal and regional transit authorities eligible for the bonds.
- Extend the existing tax credit for electric vehicle charging infrastructure through 2018 and expand the range of eligible costs.
- Allow immediate expensing of GEV purchases and supporting infrastructure for operators of certain fleets.
- Make tax credits for the purchase of qualifying grid-enabled vehicles and related charging infrastructure transferable.
- Incentivize the establishment of special purpose entities to facilitate bulk purchasing of electric drive vehicles by fleet operators.

**Other Policy Recommendations**

- Reinstate and extend the credit for medium- and heavy-duty hybrid electric vehicles that utilize advanced batteries.
- Establish a program to guarantee the residual value of the first generation of large-format automotive batteries put into service between 2010 and 2013.
- Increase federal investment in advanced battery research and development.
- Ensure that federal motor vehicle regulations do not unnecessarily prohibit the development and deployment of cost-effective PHEVs in large trucks.
- Clarify the tax code to ensure that Section 30D GEV tax credits are available to consumers who purchase a GEV (without a battery) and lease the battery from the dealer or a third party at the time the vehicle is purchased.
ABSTRACT
The electric vehicle industry has gained significant momentum over the past several years. Strong investment from the private and public sectors has placed the United States on a path to global competitiveness in advanced battery manufacturing, and there appears to be strong demand for the first wave of grid-powered vehicles. Electric vehicles offer the possibility of a transportation sector delinked from oil, which would dramatically improve economic and national security while reducing emissions. While personal-use passenger vehicles will continue to be the key market, other targets—such as commercial and government fleets—could help drive early demand.

Two years after Congress passed and the president signed the American Recovery and Reinvestment Act (ARRA), the legislation’s impact on transportation electrification is becoming apparent. At the beginning of 2009, the United States was on a path to develop little if any domestic capacity in large-format lithium-ion battery manufacturing. Strong policy support and a well-entrenched consumer electronics battery industry in Asia along with engraved high fuel prices in Europe had given other countries a significant head start, and the United States was poised to miss out on a multi-billion dollar global industry. Instead, by the end of 2009, $1.98 billion in grants had been provided to more than 30 awardees for the manufacture of advanced batteries, battery and drive-train components, and other activities, including battery recycling. Nearly 20 other awardees received a total of $356 million in transportation electrification funds.

ARRA also revised electric vehicle tax credits for U.S. consumers. Under the new law, U.S. residents who purchase electric-drive vehicles that draw power from the grid will be able to claim a base tax credit of $2,500 for a vehicle with a battery of at least five kilowatt hours (kWh) and $4,477 dollars per kWh from five upward, capping at an additional $11,000. The maximum tax credit, therefore, is $7,500. The credit applies to the first 200,000 vehicles per manufacturer, and there is no specific limit on the number of qualifying manufacturers.

In addition, the Department of Energy (DOE) distributed $800 million in stimulus funds to 25 recipients in the Clean Cities Program. The majority of the funds were targeted toward deploying alternative fuel infrastructure in U.S. cities participating in the program. Funds will support the construction of electric vehicle charging infrastructure as well as refueling stations for compressed natural gas (CNG), liquefied natural gas (LNG), biofuels and other alternative-fueled vehicles.

Beginning in 3Q 2010, the first stimulus-supported batteries began rolling off assembly lines in Michigan and Indiana. By 2012, 30 factories with the capacity to produce an estimated 20 percent of the world’s advanced batteries will exist in the United States. By 2015, these facilities could produce enough batteries and components to support 500,000 plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs).

At the same time, the first commercial deliveries of a wave of new grid-enabled vehicles (GEVs) are drawing closer. By the end of 2010, Nissan will begin selling its all-electric Leaf into select markets, and General Motors will begin selling the Chevy Volt. Nissan has announced plans for a wider market launch beginning in 2011. Ford Motor Company will introduce at least three grid-enabled vehicles by 2012, including the fully electric Transit Connect, the Focus EV, and a plug-in hybrid Escape.

A number of other significant plug-in offerings from start-up vehicle manufacturers such as Coda, Bright, and A123 Systems will help drive early demand.

Want To Learn More?
Visit ElectrificationCoalition.org to download the Electrification Roadmap or request a printed copy.
Fisker Automotive will bring currently announced North American GEV capacity to 150,000 units by 2012 and nearly 300,000 units by 2015.*

This investment in advanced battery and electric-drive vehicle technology by both the public and private sectors represents a commitment to dealing with a cross-section of key challenges confronting the United States today. Electric drive technologies—from HEV to PHEV and EV—are the most technologically mature and cost-effective means for confronting many of our nation’s most substantial economic, national security, and environmental issues. Moreover, infant industry support for the domestic battery industry is a first step—albeit a modest one—toward supporting a renewed manufacturing base in the United States. Large-format batteries make up one of the more promising components in the emerging industries that will employ American workers in the coming years.

To fully capitalize on this investment, however, electric drive vehicles must ultimately succeed in the marketplace. The supply-side of the grid-enabled vehicle industry has developed rapidly over the past several years, and the United States has begun to establish a global leadership position, particularly in the design and manufacture of large-format lithium-ion batteries. From a national perspective, however, the real challenge will be to accelerate the pace at which new technology can alter the energy profile of the U.S. transportation sector.

Technological enthusiasts and other early adopters will likely provide strong demand for the first several hundred thousand grid-enabled vehicles. But moving beyond this market will be challenging. Today, more than 10 years after their introduction to U.S. markets, there are just 1.6 million gasoline electric hybrid cars and light-duty trucks on the road in the United States. Hybrids represent less than 1 percent of the light-duty vehicle parc.

In some ways, the challenges facing consumer acceptance of grid-enabled vehicles will be greater than those that faced hybrids—though their potential benefits to the nation are also substantially greater than those of traditional hybrids. In addition to vehicle range and associated infrastructure issues, perhaps the most important challenge facing widespread adoption of grid-enabled vehicles will be cost, a factor largely determined by the battery. Most industry participants and analysts argue that battery manufacturing costs will fall as the industry timeframes for such reductions are somewhat uncertain and depend heavily on early market development. Therefore, particularly in the early stages of industry growth, it will be important to expand the demand-side of the industry by targeting a diverse customer base.
Oil and the U.S. Economy

The energy impact of reduced economic and industrial activity—as well as high unemployment—associated with the 2007–2009 recession has been significant. Total U.S. oil consumption averaged 20.6 million barrels per day (mbd) from 2003 to 2007, equal to approximately 25 percent of the global total. High fuel prices and the recessionary conditions that began in 2007 drove oil demand down by nearly 10 percent—from 20.7 mbd in 2007 to 18.7 mbd in 2009, its lowest level since 1997.12 In 2008 and 2009, oil consumption in the United States experienced two consecutive years of decline for the first time in 19 years.13 Total petroleum supplied is slightly up in 2010 at 19.3 mbd, but is well below recent averages.14 As the U.S. economy continues to shift away from heavy industry, and as strengthened fuel-economy standards begin to impact the efficiency of new American cars and trucks, many analysts are predicting the advent of ‘peak demand’ for fuels such as gasoline in the United States.15

And yet, the United States is still heavily reliant on petroleum. In large part, this is because the United States still possesses the world’s largest, most dynamic transportation system. At more than 14 million barrels per day, this sector alone consumes more oil than any other individual national economy in the world. There are more than 250 million light-duty vehicles on U.S. roads today, accounting for approximately 40 percent of total oil consumption.16 Freight trucks add another 9.7 million vehicles, equaling roughly 12 percent of oil demand.17 All told, the transportation sector accounts for 71 percent of aggregate U.S. oil consumption.18 Despite significant efforts to drive alternative fuels into the marketplace, 94 percent of delivered energy in the transport sector is still petroleum-based today.19

Simply put, oil consumption and the mobility provided by petroleum fuels represent core components of the national economy and American way of life. Petroleum meets nearly 40 percent of total U.S. primary energy needs, more than any other energy source.20 Aggregate consumer expenditures on petroleum products were as high as 6.4 percent of GDP in 2008 and are on track to be as much as 5 percent of GDP in 2010.21

Most conventional forecasts envision steady increases in total U.S. petroleum consumption between 2010 and 2035. Recent Department of Energy (DOE) scenarios project a modest decline in gasoline consumption by 2035 relative to pre-recession levels, but most other petroleum products are projected to experience significant growth. Overall, liquid fuels consumption increases by 6.8 percent by 2035 in DOE’s outlook.22 Diesel and jet fuel consumption also increase by wide margins. The U.S. driving population is expected to increase from approximately 237 million people in 2007 to 311 million by 2035, leading to a 34.3 percent increase in light-duty vehicle miles traveled.23 Freight miles traveled are expected to increase by a staggering 51 percent by 2035.24

Light-, medium-, and heavy-duty trucks represent one of the most significant growth segments for U.S. oil demand, just as they have for several decades. Since 1973, 100 percent of the growth in on-road U.S. oil consumption has been due to rising truck demand—an increase of 3.9 million barrels per day.25 Though lower in absolute numbers, these vehicles tend to be inefficient relative to passenger cars and also typically log much higher levels of annual vehicle miles traveled. Continued U.S. oil dependence is neither desirable nor sustainable. Over the past several years, Americans have been reminded of the serious economic, national security, and environmental costs of consuming and producing petroleum at current levels. Whether or not these costs are reflected in the retail price of gasoline, they are both real and significant.
Economic Costs of Oil Dependence

Although the United States remains the third largest producer of petroleum in the world, U.S. oil production has fallen dramatically from its peak in 1970 as the size of new discoveries has fallen and the productivity of new wells has declined. America now imports 58 percent of the oil it consumes, at tremendous cost to the current account balance. In 2007, the U.S. trade deficit in crude oil and petroleum products was $295 billion. In 2008, as oil prices reached all time highs, that figure increased to $388 billion. Based on current levels of oil imports and petroleum prices, the U.S. trade deficit in crude oil and petroleum products is on pace to return to pre-crisis levels near $300 billion in 2010.

The share of petroleum trade in the overall U.S. trade deficit has increased considerably in recent years. Since December 2007, crude oil and petroleum products have routinely accounted for more than half of the monthly U.S. trade deficit. For the full year, oil trade accounted for 56 percent of the total U.S. trade deficit in 2008 and 55 percent in 2009. In other words, oil now typically accounts for a greater share of the U.S. trade deficit than trade with any single bilateral or regional trade partner, such as China, NAFTA or the EU. While more than 30 percent of net U.S. imports are sourced in North America, 48 percent originate with OPEC member states with which the United States has little else in the way of economic relationships. A significant share of the dollars sent abroad to purchase oil from OPEC states is not recycled into the U.S. economy, amounting to a simple transfer of wealth.

Direct wealth transfer is only one of the many economic costs of American oil dependence. Researchers at the Oak Ridge National Laboratories (ORNL), have studied at least two others. First, significant economic costs stem from the temporary misallocation of resources as the result of sudden price changes. When oil prices fluctuate, it becomes difficult for households and businesses to budget for the long term, and economic activity is significantly curtailed. Second, the existence of an oligopoly inflates oil prices above their free-market cost. As a result, some economic growth is foregone due to higher costs for fuel and other products. ORNL studies estimate the combined damage to the U.S. economy from oil dependence between 1970 and 2009 to be $4.9 trillion in current dollars. For 2008 alone, the cost was nearly $500 billion.

Perhaps most tangibly, every recession over the past 35 years has been preceded by or occurred concurrently with an oil price spike. In general, recessions are caused by a myriad of factors and are damaging to nearly all sectors of the economy. And yet, oil price spikes tend to exact a particularly heavy toll on fuel-intensive industries like commercial airlines and shipping companies. Additionally, automobile manufacturers tend to suffer disproportionately as consumers dramatically scale back large purchases. But most important is the effect that oil prices have on consumer spending, which represents about 70 percent of the economy. Stated simply, when consumers spend more on gasoline (and heating oil), they spend less on everything else.

Since December 2007, crude oil and petroleum products have routinely accounted for more than half of the monthly U.S. trade deficit.

Oil tanker moored in loading bay of oil refinery in Houston, Texas.

Source: Figures 6-7: U.S. Census Bureau; Figure 7-7: U.S. Bureau of Economic Analysis; Figure 7-8: Greene, David L., and Janet L. Hoppes. “The Costs of Oil Dependence 2009” Special Section.

25 DOE, AER 2000, Figure 5.2.
26 Id., Table 5.1 and 5.9.
27 Id., Table 5.8.
28 DOE, EIA, October 2010 Short Term Energy Outlook, and DOE, EIA, Weekly Petroleum Status Report (October 6, 2010); AER analysis.
29 U.S. Census Bureau, Office of Foreign Trade Statistics, EC analysis.
30 Id.
31 DOE, AER 2009, Table 5.4.
33 Id.
That the United States will protect the free flow of oil with this for decades, and have made it a matter of stated policy severe economic dislocation. U.S. leaders have recognized East or the closure of a key oil transit route would lead to today. A prolonged interruption due to war in the Middle among the most immediate threats to the United States options when dealing with problems in these nations. A crippling disruption to global oil supplies ranks the world’s oil supply. Second, the importance of large individual oil producers constrains U.S. foreign policy the world’s oil supply. Second, the importance of large individual oil producers constrains U.S. foreign policy among the most immediate threats to the United States today. A prolonged interruption due to war in the Middle East or the closure of a key oil transit route would lead to severe economic dislocation. U.S. leaders have recognized this for decades, and have made it a matter of stated policy that the United States will protect the free flow of oil with military force. Still, policy alone has consistently fallen short of complete deterrence, and the risk of oil supply interruptions has persisted for nearly 40 years.

To mitigate this risk, U.S. armed forces expend enormous resources protecting chronically vulnerable infra-
structure in hostile corners of the globe and patrolling oil transit routes. This engagement benefits all nations, but comes primarily at the expense of the American military and ultimately the American taxpayer. A 2009 study by the RAND Corporation placed the ongoing cost of this burden at between $67.5 billion and $83 billion annually, plus an additional $8 billion in military operations. In proportional terms, these costs suggest that between 12 and 15 percent of the current defense budget is devoted to guaranteeing the free flow of oil.

Foreign policy constraints related to oil dependence are less quantifiable, but no less damaging. Whether dealing with uranium enrichment in Iran, a hostile regime in Venezuela, or an increasingly assertive Russia, American diplomacy is distorted by our need to minimize disruptions to the flow of oil. Perhaps more frustrating, the importance of oil to the broader global economy has made it nearly impossible for the United States to build international consensus on a wide range of foreign policy and humanitarian issues.

Environmental Sustainability

The environmental externalities of oil production and consumption are increasingly coming into focus. Total U.S. energy-related CO₂ emissions were 5,405 million metric tons in 2009. Emissions from the combustion of petroleum accounted for 43 percent of the total, representing a significantly larger share than emissions from coal use.

From a sectoral perspective, electric power represents the largest source of energy-related CO₂ emissions, accounting for 2,152 million metric tons in 2009. Coal emissions make up more than 80 percent of the total U.S. power emissions profile. However, these figures represent upstream emissions that result from economy-wide usage of electricity. In order to assess the impact of energy consumption of different sectors of the economy, it is also useful to consider emissions from the primary end-use sectors reported by the Department of Energy: the industrial, commercial, residential, and transportation sectors. End-use figures incorporate the full consumption of energy by a sector, including electricity and other energy forms.

From an end-use perspective, the transportation sector is the single largest source of U.S. CO₂ emissions, having surpassed industrial emissions in 1999. Total CO₂ emissions from transportation were 1,851 million metric tons in 2009, and 98 percent of these emissions were from petroleum consumption. In 2009, consumption of petroleum in the transportation sector accounted for more U.S. energy-related CO₂ emissions than the consumption of coal for electric power production.

International consensus is increasingly focused on reaching atmospheric greenhouse gas concentrations of 450 parts per million by mid-century in order to avoid the most severe impacts of climate change. This scenario would require energy-related CO₂ emissions to be reduced by 40 percent from 2006 levels in developed countries while other major economies limit their growth to 20 percent. These reductions would require significant replacement of petroleum transportation fuels.

In addition to negative externalities associated with the consumption of petroleum, the consequences of petroleum production were also highlighted in 2010. On April 20, 2010, an oil and gas exploration rig in the Gulf of Mexico experienced a catastrophic blowout, resulting in an explosion and fire. Two days later, the
28

29

As a result, IOCs have increasingly
commonly located in countries or regions that do not permit
exist in substantial quantities, but they are most com-
Asia-Pacific. To be sure, low-cost proven oil reserves still
the United States, Western Europe, and industrialized
regions most accessible to international oil companies—
conventional oil and gas supplies is dwindling in the
not risk-free. The availability of relatively inexpensive
well was stabilized on July 15.

of crude oil into the Gulf of Mexico before the damaged
incident likely released several million barrels
primer: electrification of the transportation sector fleet electrification roadmap

emissions—less than 2 percent of global demand.

the regions in which they can operate.66

expanded the boundaries of technological possibilities in
the regions in which they can operate.66

Finding and developing these fuels is costly and tech-
and deepwater oil and gas explora-
tion is expected to be at the forefront of industry efforts

is on pace for a 9 percent gain in 2010.44 More broadly,
emerging market energy demand growth now sets the
pace for the world. In particular, the rapid increase in
demand for mobility in the developing world is reshap-
ing the global oil market. Oil demand growth in emerging
market economies has averaged 3.6 percent annually
since 2000, resulting in a net increase in demand of 9.6
million barrels per day between 2000 and 2009.45 The
majority of this increase was for transportation. Oil
demand in the developed world actually shrank over the
same period. Together, China and India have accounted
for 63 percent of the total global increase in oil demand
since the start of the century.46

FIGURE P10
Share of Energy-Related CO₂ Emissions by Fuel & Use

FIGURE P11
Energy Related CO₂ Emissions, End Use

Source: Figure P10 — DOE, AER 2009, Figure P11 — DOE, AER

Assessing Energy Markets over the Medium Term

The factors that led to high oil prices and increased vola-
tility in the global oil market in recent years are not likely
to significantly alter over the medium and long term.
Rising demand in emerging market economies coupled
with constrained growth in oil supplies is a fundamental
dynamic that has already been factored into crude oil
prices.

Undeterred by the global economic downturn, China
clocked a 6 percent increase in oil demand in 2009 and
is on pace for a 9 percent gain in 2010.44 More broadly,
emerging market energy demand growth now sets the
pace for the world. In particular, the rapid increase in
demand for mobility in the developing world is reshap-
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market economies has averaged 3.6 percent annually
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for 63 percent of the total global increase in oil demand
since the start of the century.46

46 IEA, World Energy Outlook 2009, Table 1.3.

44 DOE, EIA, Short Term Energy Outlook, Custom Table Builder; available
online at http://www.eia.doe.gov/emeu/steo/pub/cf_query/index.cfm,
last accessed October 26, 2010.
43 BP, plc., Historical Review of World Energy 2009, at 11.

FIGURE P12
Light Duty Vehicle Stock by Region


48 IEA, WEO 2009, Table 1.5.

47 DOE, EIA, Short Term Energy Outlook, Custom Table Builder; available
online at http://www.eia.doe.gov/emeu/steo/pub/cf_query/index.cfm,
last accessed October 26, 2010.

Russian demand has been especially robust, and now
Russia
Japan
India
China
United States
European Union

energy-related CO₂ emissions

Source: Figure P11 — DOE, AER 2009; Figure P10 — DOE, AER

41 International Energy Agency (IEA), World Energy Outlook 2008 (WEO 2008), Table 14.1.
40 IEA, World Energy Outlook 2008 (WEO 2008), Table 1.4.
production within the world’s most developed nations—the 30 members of the Organization for Economic Co-operation and Development (OECD)—peaked in 1997 and has markedly declined each year since 2002.48 Outside the OECD, the picture is no more encouraging. More than 90 percent of global oil supplies are owned by state-run national oil companies (NOCs).49 While a handful of NOCs operate like private firms at the technological frontier of the industry, the majority function essentially as a branch of their respective central governments, depositing oil revenues in the treasury, from which they are often diverted to other programs instead of being reinvested in new energy projects.50

Meanwhile, the fraction of global oil reserves that is accessible to international oil companies (IOCs) is growing increasingly complex and costly to produce.51 In addition to the typical costs for pipelines, tankers, and refineries, IOCs must now invest significant additional capital per barrel of oil produced for specialized drilling equipment, oversized offshore platforms, and advanced upgrading facilities. As a result, the cost of production for incremental non-OPEC oil reserves has increased rapidly in recent years. Currently, the break-even price for Canadian oil sands is estimated at between $50 and $80 per barrel.52 For projects in the Gulf of Mexico, marginal costs are estimated to be $60 per barrel.53 Promising basins off the coast of Brazil, the West Coast of Africa, and the Former Soviet Union are equally complex and costly. With these factors in mind, a strong case can be made that high oil prices are here to stay.

In fact, oil prices and supply-demand dynamics that have occurred in the global oil market throughout 2010 have served to reinforce this case. With global oil demand still recovering from the shock of the financial crisis, non-OPEC spare capacity is currently 1.1 million barrels per day, a level last witnessed throughout 2001 and 2002, when oil prices averaged $20 to $30 per barrel.54 Current commercial inventories are also at generous levels. U.S. commercial crude oil stocks were 358 million barrels as of late September 2010, more than 15 percent above recent averages for September.55 Gasoline and diesel stocks are similarly bloated, and the story is roughly the same throughout the world. The world is awash in oil and global demand is only now returning to pre-crisis levels. And yet, crude oil prices have averaged more than $75 per barrel throughout 2010, a level that would have seemed exorbitant as recently as 2003.

Electrification of transportation remains the most promising near-term opportunity for fundamentally reducing U.S. dependence on petroleum. Traditional gasoline electric hybrid electric vehicles (HEVs) offering gasoline efficiency improvements of 25 to 50 percent—or more—for a midsize car have been available for a decade and the technology is generally mature.56 More recently, there have been significant advancements in the technology needed to produce vehicles that can charge onboard batteries with electricity from the grid, offering a fundamental break from petroleum consumption in transportation. Though important challenges remain, the global automotive industry has invested heavily in a number of grid-powered vehicle platforms that allow for various ranges of autonomous driving powered solely by electric- ity. In general, grid-enabled vehicles can be either pure electric vehicles (EVs) or plug-in hybrid electric vehicles (PHEVs). Both EVs and PHEVs store energy from the grid in on-board batteries. Energy from the battery powers a highly-efficient electric motor that propels the vehicle. EVs substitute an electric drivetrain for all conventional drivetrain components. PHEVs retain the use of a downsized internal combustion engine that supplements bat- tery power.

To be sure, continued improvements in the internal combustion engine—along with the targeted uptake of other alternative fuel vehicle technologies—can and should play a role in efforts to improve U.S. energysecurity. However, grid-enabled vehicles offer an entirely new prospect: a transportation system drenched from oil. Convergence between the power and transport sectors could fundamentally alter the U.S. energy security equation. Vehicles powered by electricity from the grid consume no petroleum while they are operating on energy discharged from the battery. The benefits of such a propulsion system are enhanced by key features of the electric power sector as well as the vehicle tech- nology itself.

Electrification of transportation remains the most promising near-term opportunity for fundamentally reducing America’s dependence on oil.
Today’s familiar hybrid-electric vehicles offer improved efficiency over traditional internal combustion engine automobiles. However, by incorporating a larger battery and drawing electric power from the grid, plug-in hybrids and pure electric vehicles offer a step change improvement in energy security.

**FIGURE 16**

Vehicle Configurations

**INTERNAL COMBUSTION ENGINE VEHICLE**
- Engine
- Transaxle
- Fuel System

**HYBRID-ELECTRIC VEHICLE (HEV)**
- Transaxle
- Electric Motor
- Battery
- Fuel System

**PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)**
- Transaxle
- Electric Motor
- Battery
- Fuel System

**ELECTRIC VEHICLE (EV)**
- Transaxle
- Electric Motor
- Battery

**KEY FEATURES**
- Traditional IC engine vehicles store liquid fuel—typically gasoline or diesel—onboard in a fuel tank. Fuel is combusted in the engine, which delivers mechanical energy to the axle to propel the vehicle. The high energy density of gasoline and the ability to store significant volumes of fuel onboard allow IC engine vehicles to travel several hundred miles without refueling. Today’s internal combustion engines, however, are highly inefficient. IC engine automobiles turn less than 20 percent of the energy in gasoline into power that propels the vehicle. The rest of the energy is lost to engine and driveline inefficiencies and idling.

**KEY FEATURES**
- HEVs retain the use of an IC engine, and therefore require a liquid fuel tank. Additional energy is stored in a battery, from which electricity flows to an electric motor. The motor transforms electrical energy into mechanical energy, which provides some measure of torque to the wheels. In a typical parallel hybrid system, both the engine and the motor provide torque to the wheels. In a series hybrid system, only the electric motor provides torque to the wheels, and the battery is charged via an onboard generator. Power split systems utilize two electric motors and an IC engine. Both the engine and the larger electric motor can provide torque to the wheels—jointly or independently.

**KEY FEATURES**
- Like traditional hybrids, PHEVs retain the use of an internal combustion engine and fuel tank while adding a battery and electric motor. However, PHEVs utilize much larger batteries, which can be charged and recharged by plugging into the electric grid. PHEV batteries are capable of powering the vehicle purely on electricity at normal speeds over significant distances (approximately 40 miles) without any assistance from the IC engine. When the battery is depleted, PHEVs use the IC engine as a generator to power the electric motor and extend their range by several hundred miles. PHEVs can be configured as a series hybrid system or a power split system.

**KEY FEATURES**
- EVs do not incorporate an IC engine or conventional fuel system. Electric vehicles rely on one or more electric motors that receive power from an onboard battery to provide the vehicle's propulsion and operation of its accessories. EV batteries, which are typically larger than batteries in HEVs or PHEVs to support vehicle range, are charged by plugging the car into a device (electric vehicle service equipment) that receives electrical power from the grid.

**HYBRID ELECTRIC VEHICLE SYSTEMS**

**MILD HYBRID (PARALLEL SYSTEM)**
- Still relies heavily on IC engine
- Efficiency gains of 15 to 20 percent
- Battery provides additional power during acceleration; powers the AC and other systems during idling
- Regenerative braking charges battery

**FULL HYBRID (POWER-SPLIT SYSTEM)**
- Still relies on IC engine, but less than mild hybrid
- Efficiency gains of 25 to 40 percent
- Larger battery provides enough power for autonomous driving at low speeds
- Smaller motor acts as generator to charge the battery

**PLUG-IN HYBRID ELECTRIC VEHICLE SYSTEMS**

**PHEV (SERIES HYBRID SYSTEM)**
- Only electric motor provides torque to wheels
- IC engine serves only to augment the battery after depletion
- Uses no gasoline while battery is sufficiently charged
- Charges battery through grid connection and regenerative braking

**PHEV (POWER-SPLIT SYSTEM)**
- Both the motor and IC engine can provide torque to the wheels
- IC engine provides torque when required (blended mode)
- Charges battery through grid connection and regenerative braking
The Advantages of Electric Drive

Electric drive technology offers a significant improvement in efficiency within a given vehicle class when compared to a comparable traditional internal combustion engine vehicle. In large part, this is due to the high efficiency of electric motors, which can convert as much as 80 to 90 percent of the energy content of electricity into mechanical energy. This efficiency contributes to several significant benefits for the vehicle operator.

Reduced Fuel Costs: Electric drive offers significant reductions in fuel costs on a per-mile basis. With gasoline at $3.00 per gallon, a relatively efficient internal combustion engine vehicle rated at 30 miles per gallon has an average fuel cost of 10 cents per mile. A mid-sized sport utility vehicle getting 20 miles per gallon has an average fuel cost of 15 cents per mile, and a medium-duty urban delivery vehicle getting 10 miles per gallon has an average fuel cost of 30 cents per mile. Comparatively, a light-duty battery electric vehicle or a PHEV in charge-depleting mode would have fuel costs of just 2.5 cents per mile, assuming electricity priced at 10 cents per kilowatt hour (kWh) and an electric motor efficiency of 4 miles per kWh. At 2.0 miles per kWh, the fuel cost for a medium-duty PHEV or EV truck would be 5 cents per mile.

Efficient Use of Energy: Low fuel costs for EVs and PHEVs are partially a function of the low price of electricity on an energy-equivalent basis. They are also a function of the efficiency of electric motors. However, all electric drive technologies also make efficient use of energy from the point of combustion. For EVs and PHEVs, assessing that efficiency requires moving up the energy system to the point where fuel is combusted in a power plant. Using this measure, the efficiency advantage of electric drive is readily apparent. A traditional ICE vehicle getting 30 mpg can travel less than one-fourth of a mile on the energy contained in 1,000 Btu of gasoline. An electric vehicle or PHEV in charge-depleting mode can travel nearly double that distance on 1,000 Btu of natural gas. This efficiency advantage of electric drive, even accounting for line losses in transmitting the electricity from the power plant.

Reduced Emissions: Electric drive technology can provide significant reductions in CO₂ emissions compared to conventional vehicles powered by fossil fuels. Today’s full hybrids offer as much as a 30 percent improvement in emissions when compared to similarly sized conventional gasoline vehicles. Questions have been raised about the emissions profile of PHEVs and EVs, because approximately 48 percent of current U.S. electricity generation is derived from coal-fired power plants. Together with natural gas, fossil fuels account for as much as 70 percent of U.S. power generation.

However, the emissions benefits of electric drive vehicles are still significant. A number of well-to-wheels analyses have quantified emissions benefits of electric drive technology in recent years. One study from the Natural Resources Defense Council and the Electric Power Research Institute found that a PHEV-20 powered by electricity from the grid offered significant emissions benefits, even if 100 percent of the electricity used to power the vehicle was generated at a relatively inefficient coal plant. And in fact, despite the prominent role that coal-fired electricity generation plays in the U.S. power portfolio, the notion of a PHEV or EV powered 100 percent by coal is somewhat misleading. This is because vehicles plugging into the grid will be powered by the lowest-cost source of dispatchable power generation at a given point in time. More often than not, the marginal fuel is unlikely to be coal, as coal typically serves as a source of baseload power, and ramping coal generation requires some measure of planning. Instead, the marginal fuel powering PHEVs and EVs is likely to be natural gas in much of the United States. Natural gas is low cost and easily dispatchable.

As a fuel, natural gas contains about 30 percent less CO₂ than oil and 45 percent less than coal on an energy equivalent basis. Moreover, the platform in which the fuel is consumed impacts emissions significantly. On average, the fleet of U.S. coal power plants currently has a 32 percent efficiency rating. In contrast, the current natural gas-fueled power fleet reaches roughly 43 percent, and it has been improving substantially as combined cycle gas plants are deployed in greater numbers. Current-generation combined cycle plants reach efficiency levels of 60 percent, which, when combined with the lower carbon profile of gas, results in an emissions reduction of about 70 percent per unit of electricity generated versus the existing coal fleet.

One recent study from the Oak Ridge National Laboratory simulated the impact of significant adoption of PHEVs throughout the United States. The study assumed that more than 19 million PHEVs would be on the road by 2020, and it plotted penetration across different National Electric Reliability Council (NERC) regions. Aggregated across all NERC regions, the study found that natural gas generation provided for the bulk of added electricity generation needed to power PHEVs in a variety of charging scenarios. Most recently, Argonne National Laboratory simulated the well-to-wheels emissions profile of a number of PHEVs with varying battery sizes in different regions of the United States. The analysis found that a PHEV-40 in charge-depleting (CD) mode had significantly lower CO₂ emissions than a conventional gasoline vehicle in each region analyzed, and in most cases the PHEV-40 in CD mode outperformed a traditional HEV. In Illinois, a coal-dominated region, the PHEV still offered an emissions improvement over a conventional gasoline vehicle, while HEVs performed the best out of the technologies evaluated.

(The drive cycle used in the Argonne analysis resulted in a 11 percent utility factor for a PHEV, which is on the conservative side.)

Energy Security: Electric drive systems represent a substantial improvement from an energy security perspective. The Marginal Energy Source (MES) calculation assumes a hydrogen supply chain that is not based on fossil fuels or nuclear power. For this reason, the marginal energy source for a PHEV is likely to be hydrogen, which is derived from natural gas. The hydrogen is then processed into a liquid fuel, which is then supplied to the PHEV.

In addition, the fuel for a PHEV is more difficult to disrupt than the fuel for a gasoline vehicle. Natural gas can be stored in large quantities, and it is not subject to the same types of supply chain disruptions as gasoline. This makes it an attractive option for military and emergency vehicles. Furthermore, electric drive systems can be used in a variety of applications, including forklifts, buses, and trains, which can be powered by energy storage systems such as batteries.

In summary, electric drive technology offers significant benefits for the vehicle operator, including reduced fuel costs, reduced emissions, and improved energy security. These benefits make electric drive a promising technology for the future of transportation.
standpoint. Electric vehicles—and series plug-in hybrid electric vehicles operating in charge-depleting mode—essentially use zero petroleum to propel the vehicle. In some configurations, PHEVs with smaller batteries may still use some petroleum, but the total amount can be nearly 50 percent lower than from an HEV. Meaningful penetration of EVs and PHEVs, along with traditional HEVs and more efficient ICE vehicles, would radically improve U.S. energy security by minimizing the role that petroleum plays in the national economy.

Between 1975 and 1985, the United States sharply reduced the amount of petroleum that went into producing each dollar of gross domestic product. The practical elimination of oil from the electric power sector and the implementation of the first national fuel economy standards led to oil intensity reductions averaging 2.5 percent per year. Beginning in 1985, however, the rate of reductions in oil intensity slowed dramatically. A crash in oil prices strongly contributed to changing consumer demand in vehicle performance and fuel efficiency metrics. Over the following decades, reductions in oil intensity averaged less than 1 percent annually, as improvements in fuel-economy standards stalled and the automotive industry invested research and development dollars in increasing horsepower instead of the advance of new, efficient technologies.

The arrival of electric-drive vehicles in the market signals the beginning of a fundamental shift in U.S. energy security dynamics. With oil demand growth in emerging market economies providing steady support for higher oil prices, consumers may be much more willing to invest in efficiency if the product options are compelling.

The Benefits of Electricity

Grid-enabled electric drive technologies—PHEVs and EVs—will benefit from important characteristics of the U.S. electric grid. Vehicle miles powered by electricity will offer improved energy security, reduced fuel costs, and reduced CO2 emissions largely because the power sector offers material improvements in those categories compared to petroleum.

**Electricity is Diverse and Domestic:** Electricity is generated from a diverse portfolio of largely domestic fuels, including coal, uranium, natural gas, flowing water, wind, geothermal heat, the sun, landfill gas, and others. Among those fuels, the role of petroleum is negligible. In fact, just 1 percent of power generated in the United States in 2009 was derived from petroleum.

An electricity-powered transportation system, therefore, is one in which an interruption of the supply of one fuel can be made up for by others, even in the short term, at least to the extent that there is spare capacity in generators fueled by other fuels, which is generally the case. This ability to use different fuels as a source of power would increase flexibility in the transport sector. As national goals and resources change over time, the United States could shift transportation fuels without overhauling its transportation infrastructure.

In addition to this diversity of supply, the fuels used to generate electricity are generally sourced domestically. All renewable energy is generated using domestic resources. The United States is a net exporter of coal. In 2009, only 12 percent of natural gas demand was met by imports, and approximately 90 percent of those imports were from North American sources (Canada and Mexico). The United States does import a substantial portion of the uranium that fuels civilian nuclear power reactors. Forty-two percent of those imports, however, are from Canada and Australia.

**Electricity Prices are Stable and Relatively Inexpensive:** Electricity prices are significantly less volatile than oil or gasoline prices. Over the past 25 years, electricity prices have risen steadily but slowly. Since 1985, the average nominal retail price of electricity delivered in the United States has increased by an average of less than 2 percent per year in nominal terms and has actually fallen in real terms. Moreover, nominal prices have risen by more than 5 percent year-over-year only three times in that time period. This price stability, which is in sharp contrast to the price of oil or gasoline, exists for at least two reasons.

First, the retail price of electricity reflects a wide range of costs, only a small portion of which arise from the underlying cost of fuel. The remaining costs are largely fixed. In most instances, the cost of fuel represents a smaller percentage of the overall cost of delivered electricity than the cost of crude oil represents as a percentage of the cost of retail gasoline. For instance, although fossil fuel prices rose 21 percent between 2004 and 2006 (as measured on a cents-per-Btu basis), and the price of uranium delivered in 2006 rose 48 percent over the cost of uranium delivered in 2004, the national average retail price of all electricity sales increased only 17 percent. This cost structure promotes price stability with respect to the final retail price of electricity.

Second, although real-time electricity prices are volatile (sometimes highly volatile on an hour-to-hour or
day-to-day basis), they are nevertheless relatively stable over the medium and long term. Therefore, in setting retail rates, utilities or power marketers use formulas that will allow them to recover their costs, including the occasionally high real-time prices for electricity, but which effectively isolate the residential consumer from the hour-to-hour and day-to-day volatility of the real-time power markets. By isolating the consumer from the price volatility of the underlying fuel costs, electric utilities would be providing to drivers of GEVs stability that oil companies cannot provide to consumers of gasoline.

The Electric Power Sector has Substantial Spare Capacity: Because large-scale storage of electricity has historically been impractical, the U.S. electric power sector is effectively designed as an ‘on-demand system.’ In practical terms, this has meant that for natural gas, the system is constructed to be able to meet peak demand from existing generation sources at any time. However, throughout most of a 24-hour day—particularly at night—consumers require significantly less electricity than the system is capable of delivering. Therefore, the U.S. electric power sector has substantial spare capacity that could be used to power electric vehicles without constructing additional power generation facilities, assuming charging patterns were appropriately managed.

The Network of Infrastructure Already Exists: Unlike many proposed alternatives to petroleum-based fuels, the nation already has a ubiquitous network of electricity infrastructure. No doubt, electrification will require additional functionality and increased investment in grid reliability, but the power sector’s infrastructural backbone—generation, transmission, and distribution—is already in place.

The Grid will Get Cleaner, not Dirtier: Changes to the composition of U.S. power generation sources are likely to further enhance the emissions benefits of plug-
ging vehicles into the grid. For decades, natural gas baseload power generation was disadvantaged by the high cost of the fuel. Natural gas prices regularly exceeded those of coal, and were also far more volatile. Despite the fact that capital costs for natural gas generation were generally well below those associated with building a new coal plant, many operators opted for coal-fired generation, preferring a stable fuel price to the relatively small component of overall plant expenditures.

However, the U.S. upstream natural gas industry has experienced a revolution in recent years. The technology to successfully exploit unconventional gas reservoirs—shale, tight sands, and coal bed methane—has unlocked a vast new domestic resource. Shale resources in particular have been a fundamental driver in expanding U.S. natural gas reserve estimates. Proved reserves have increased by 37 percent since 2000, from 177 trillion cubic feet (tcf) to 244 tcf. Yet, proved reserves present only part of the picture. The Colorado School of Mines Potential Gas Committee estimates that potential U.S. gas reserves could now be closer to 2,000 tcf, resulting in a theoretical reserves-to-production ratio of nearly 100 years at today’s consumption levels.

The cost structure for natural gas production from onshore unconventional resources is also shifting the energy landscape. A number of recent analyses suggest that a significant portion of U.S. resources can be produced for less than $6.60 per million Btu. This structural shift in production costs—along with significantly reduced industrial demand for natural gas during the recession—has placed substantial downward pressure on natural gas prices. As a result, natural gas prices have approached parity with coal prices a number of times since 2009, making the fuel more attractive for utilities. In fact, natural gas traded at a discount to coal in some regions in 2009 and early 2010.

The availability of abundant domestic gas resources is likely to provide momentum for a shift to gas-fired power over the coming years. This shift to lower carbon fuel in plants that achieve higher efficiency rates will result in a reduced carbon profile for the U.S. power sector, a trend that benefits electric drive technology. Moreover, even in the absence of a nationwide price on carbon, new regulatory requirements may accelerate the retirement of a portion of the U.S. coal fleet.

In July 2010, the Environmental Protection Agency proposed new air quality rules designed to reduce emissions of sulfur dioxide and nitrogen oxides from coal-fired power plants. The proposed rules would require the deployment of best available control technologies, including selective catalytic reduction (SCR) and flue gas desulfurization (FGD) units at coal-fired plants. Currently, only 103 gigawatt hours (gWh) of U.S. coal-fired electricity generation contains both SCR and FGD units. Though EPA’s rules are not finalized as of October 2010, trends in air quality management suggest a very real possibility that a substantial portion of the U.S. coal fleet will be turning over during the coming years, increasing the likelihood that EVs and PHEVs will be powered by fuel sources other than coal—most commonly natural gas.

80 Credit Suisse, The Impact of Shale Gas, at 18, (September 24, 2010).
Eighteen months after the official end of the 2007-2009 recession, the U.S. employment outlook remains troubling. Current figures place the official U.S. unemployment rate at 9.6 percent, and expectations are that the jobless rate will average 9.6 percent in 2011, well above normal levels. In short, while the Great Recession officially ended in 2009, many Americans are still waiting to feel the recovery.

Through nearly all sectors of the economy have yet to resume hiring in earnest, manufacturing employment has been hit particularly hard. Since the recession began in December 2007, the United States has shed nearly 2.1 million manufacturing jobs, and total manufacturing employment now stands at just 11.7 million workers—a 32 percent decline from January of 2001. And while only 1 in 10 Americans are currently employed in manufactur- ing, the erosion of the domestic industrial base has clearly stunted efforts to stimulate aggregate job creation.

The past several years also witnessed an inflection point in the global industrial landscape: 2009 marked the first year in which U.S. manufacturing capacity trailed Chinese capacity in its share of the world total. The ascendancy of Chinese manufacturing can be attributed to a myriad of industries and factors, but it has in part been driven by the rise of the Chinese motor vehicle industry. Chinese production of motor vehicles first surpassed U.S. output in 2008, and the gap increased by a wide margin in 2009. Total Chinese vehicle production reached 13.7 million units last year—an increase of nearly six-fold from the beginning of the decade, and more than double the U.S. total of 5.7 million domestically-made units.

In the United States, the twin shocks of rapidly escalating gasoline prices between 2007 and 2008 and the severe recession that followed through 2009 exacted a significant toll on the auto industry. Total auto sales averaged 16.1 million annualized units in 2007. As oil prices steadily rose throughout 2008, sales plummeted, falling 20 percent off their 2007 mark. The recession and financial crisis pushed auto sales to a low of just 9.2 million annualized units in September 2009, and by August 2010 sales had rebounded to just 11.3 million annualized units. As a result of reduced sales and declining domestic output, the number of U.S. workers building vehicles and their components has dropped dramatically. Between 2000 and 2009, total American workers employed in motor vehicle and auto parts production fell by more than 50 percent, from 1.13 million to approximately 560,000.

Electrification of transportation offers a rare opportunity to counter these dynamics. Early investment in advanced battery manufacturing has put the United States on competitive global footing for the jobs and other economic benefits that could be associated with this industry. Dozens of plants building advanced batteries and power electronics throughout the rust belt are already employing thousands of American workers, and a thriving domestic market for electric drive vehicles could dramatically expand this number.

The United States will face strong competition for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. The Chinese government has recently committed $15 billion to an alliance of state-run companies leading for dominance over this sector and its associated benefits. China has also announced ambitious plans to deploy EVs in up to 20 pilot cities in which strong incentives for vehicles and infrastructure will be funded by local governments as well as the national government.

Throughout Europe, high retail fuel prices and stringent tailpipe emissions standards are driving sharp increases in vehicle efficiency, and electric drive is among a handful of technologies that can meet new and forthcoming standards. Much of the technology that will power electric drive vehicles—from HEV to PHEV and EV—was invented and developed in the United States, and significant government and other economic benefits that could be associated with this industry. A comprehensiv...
Market Outlook

As a result of a number of economic and technological factors, the outlook for the North American electric drive vehicle industry remains somewhat unclear. U.S. fuel prices are relatively low by international standards, and the boom-and-bust cycle of oil prices has tended to make most consumers unwilling to invest in the higher upfront cost of more efficient vehicles. Lawmakers have also struggled to implement a comprehensive demand-side policy aimed at facilitating development of the regulatory and infrastructural network needed to maximize the benefits of EVs and PHEVs.

At the same time, a number of major global auto-makers are investing significant capital in the development of plug-in electric drivetrains. In addition to vehicles expected in U.S. markets in 2010 and 2011—primarily the Nissan Leaf and Chevy Volt—Volkswagen, BMW, Mitsubishi, Toyota, Honda, Ford, Chrysler, and others have announced significant programs to develop and market EVs and PHEVs. In some instances, these commitments are a response to increasingly stringent regulatory requirements instituted by governments. But the pace at which major OEMs are investing in EVs is nonetheless impressive.

Still, a number of technological and economic challenges remain to be addressed before electric vehicle technology can achieve mainstream potential. Many of the most significant challenges relate to battery technology. The industry continues to work toward material reductions in battery price along with improved performance metrics in some cases. However, battery prices are still too high for most typical consumers to consider purchasing electric drive vehicles. Innovative business models are emerging to deal with the high cost of capital associated with batteries, but many of these will ultimately depend on the residual value of the battery, which is yet undetermined.

Other challenges could impact the availability of charging infrastructure, both at home and in public. A reliable business model has yet to be demonstrated around public charging infrastructure, and the cost of installing the appropriate equipment in consumers’ homes could vary substantially based on the level of sophistication required. How consumers use and charge plug-in vehicles will also have a direct impact on the electric grid: smart charging will make grid-enabled vehicles an asset to the grid, unmanaged charging could make them a liability—particularly at the distribution level in some areas. A clear path to a widely deployed charging management system has not yet been outlined.

All of these factors will affect consumer acceptance of grid-enabled vehicles. As of October 2010, the first wave of offerings for both the Nissan Leaf and the Chevy Volt appear to be heavily subscribed. Nissan has reportedly received commitments for all of the fully-electric Leafs it plans to ship in 2010 and 2011. GM recently increased its planned production of Chevy Volt vehicles to as much as 15,000 units in 2011, with a possibility of increased volumes in 2012 as well. Despite these encouraging announcements, the long-term impact of electrification after these initial vehicles hit the road remains an open question. Traditional hybrids provide a case in point: in 2010, more than 10 years after the first gasoline electric hybrids were introduced in the United States, there are approximately 1.5 million HEVs on the road out of a total of 230 million light-duty vehicles. Annual hybrid sales typically account for less than 3 percent of new auto sales, and they make up less than 1 percent of the U.S. light-duty parc.

Simply stated, there are a wide range of views regarding the commercial viability of plug-in hybrid and battery electric vehicles, in the United States and globally. A sampling of forecasts from government agencies, financial institutions, consultancies, and auto industry analysts reveals estimates ranging from essentially no uptake of PHEVs and EVs to as much as 12 percent of new auto sales by 2020. The variation in these forecasts can largely be attributed to different assumptions about fuel prices, the pace of battery cost reduction, infrastructure deployment, and government policy.

This uncertainty has led some in the battery industry to caution of an imbalance between investments in battery supply and investments in supporting vehicle adoption. Forecasts vary, but some estimates project a possible 62 percent shortfall in U.S. demand for advanced large-format batteries when compared to projected capacity. However, the nature and pace of these events will be critical for determining the viability of the battery industry. If demand fails to materialize early on, much of the investment in battery capacity will be canceled or postponed, significantly setting back the industry in the United States compared to its competitors abroad.
Expanding the Demand Side

In order to capture the most significant economic, energy security and environmental benefits of electric drive technology, policymakers and auto industry participants have tended to focus their attention on light-duty vehicles. Based on the size and importance of the market, this is clearly justified. The light-duty segment alone makes up approximately 40 percent of total U.S. oil consumption and more than 60 percent of oil demand in the transportation sector. The high volume of annual light-duty vehicle sales—which even in severe recessionary conditions exceeded 10 million units per year—also means that even a relatively low sales penetration rate can result in significant uptake of a technology in absolute terms.

However, in order to support development of the electric drive vehicle industry and to help drive down industry costs for consumers, alternative vehicle markets could be important in the near-term. The early development of the electric drive vehicle and battery industries would benefit from a diverse customer base that can help drive critical volumes, particularly in the period between 2010 and 2015, when charging infrastructure and consumer acceptance issues will slow development of the personal-use passenger market. Specifically, commercial and government fleet applications stand out as highly viable market segments based on the operational needs of the vehicles and the economic factors that drive vehicle acquisition processes.

Based on total cost of ownership modeling conducted for this report, commercial and government fleets could contribute substantial volume commitments in the early development phases of the GEV market. The economic attractiveness of electric drive vehicles in certain applications—coupled with operational enhancements and targeted use of public policy levers—could drive grid-enabled vehicle penetration in U.S. commercial and government fleets to as much as 7 percent of new acquisitions by 2015. In aggregate, the market for EVs and PHEVs in fleet applications could lead to cumulative unit commitments of more than 200,000 EVs and PHEVs between 2011 and 2015. It is important to place these figures in context. Adoption of electric drive vehicles by fleet operators should not be considered a stand-alone approach to increasing energy security through reduced petroleum consumption. Ultimately, the fleet market is not significant enough to drive substantial reductions in national oil use. However, based on currently announced North American production capacity, fleet operators could represent the equivalent of up to 30 percent of total GEV component capacity in 2015. In the process, fleet operators would help expedite the development of scale efficiencies in the early GEV industry. Moreover, the tendency of fleet vehicles to be higher mileage translates into higher potential petroleum savings on a per-vehicle basis, maximizing the efficiency of early, temporary federal incentives.

These figures could represent substantial, realizable volumes during the early development of the U.S. large-format lithium-ion battery industry. Fleet customers would provide a stable customer base and much-needed certainty for manufacturers of batteries, battery components and other specialized PHEV and EV parts, including electric motors. Ultimately, the long-term predictability of large fleet commitments could help to drive cost reductions in PHEVs and EVs that would benefit the broader consumer market. In the process, fleet electrification would produce additional benefits.

First, fleet customers would contribute to driving early volumes in charging infrastructure. While centrally-parked fleets will benefit from single point installation and the ability to charge multiple vehicles per charger, fleet customers will nearly always prefer to install Level II (220v) or Level III (440v) chargers at a depot and perhaps along frequently-traveled routes as well. Electric fleets would also help utilities to consider the impact of PHEVs and EVs on the grid and begin responding to emerging issues.

Finally, fleets would help put EVs and PHEVs on the road where consumers can see them, increasing familiarity with—and perhaps acceptance of—this new, disruptive technology. In some applications, such as utility and telecommunications service vehicles or urban delivery trucks, the benefits of consumer interaction will be limited to simply observing PHEVs and EVs in operation. But in other cases, such as rental cars and taxis, electric fleets will actually provide consumers with an opportunity to interact with electric drive vehicles first-hand, building confidence through experience.

All of these benefits would support the long-term development of the electric drive industry—the most cost-effective and technologically mature option for addressing America’s dangerous dependence on oil.
PART ONE
The Case for Fleets

1.1 OVERVIEW

1.2 FLEET DEMOGRAPHICS

1.3 ADVANTAGES OF FLEETS

PUBLIC LEVEL II GEV CHARGER. The charging needs of fleet vehicles may be different than those for personal use consumers.
ABSTRACT

For electrification to meaningfully impact U.S. energy and national security, grid-enabled vehicles will ultimately need to succeed in the personal-use passenger vehicle market. However, during the early development of the electric vehicle industry, while battery and vehicle costs remain high, other market segments could prove critical for driving demand. In particular, commercial and government fleets could represent major early adopters of grid-enabled vehicles.

The lower fuel and maintenance costs associated with grid-enabled vehicles—particularly EVs—could provide more near-term economic value for fleet operators than typical consumers, particularly in higher mileage applications. Moreover, the key challenges facing widespread consumer adoption, including access to infrastructure, range anxiety, and the higher upfront costs of the vehicles themselves—might be more easily managed by fleet owners. Finally, the implementation of corporate sustainability initiatives in a number of American businesses could provide added momentum for the purchase of highly efficient electric drive vehicles in fleet applications.

CHAPTER 1.1

Overview

There were more than 16 million public and private fleet vehicles on the road in the United States in 2009. While the size of individual fleets varies significantly, the top 50 fleet operators together manage more than half a million vehicles.

Fleet vehicles perform a variety of missions for federal, state, and local government, and for companies that are familiar to nearly all Americans. They are postal delivery vehicles, utility and telecom service trucks, pharmaceutical sales vehicles, urban delivery vans, and more.

Different fleet operators take different approaches to the way they acquire, operate, and maintain their vehicles. Miles driven per day, refueling options, and the amount of time vehicles spend parked or idling can vary significantly by operator and industry. Fleet operators also take different approaches to balancing the tradeoffs between outright ownership and leasing depending on infrastructure. Fleet operators represent a customer segment that may be able to move past both challenges more quickly than typical consumers.

Miles driven per day, refueling options, and the amount of time vehicles spend parked or idling can vary significantly by operator and industry. Fleet operators also take different approaches to balancing the tradeoffs between outright ownership and leasing depending on access to infrastructure. Fleet operators represent a customer segment that may be able to move past both challenges more quickly than typical consumers.

By serving as a first market for electric drive technologies, fleet operators could generate a number of spillover benefits for the broader consumer market, easing adoption on a wider scale. Fleet operators represent a potential catalyst for the industry-wide economies of scale that will benefit the consumer electric drive market with lower prices. If plug-in vehicle adoption among fleet operators reached even 4 percent of new acquisitions by 2015, the fleet industry could generate demand for as much as 3,000 MWh of battery capacity. Increased volumes from fleet orders will also reduce the costs of electric powertrain components.

A similar impact could be realized in charging infrastructure. While fleet operators will benefit from single point installation, the need to charge multiple vehicles simultaneously in some instances could necessitate large charging unit purchase orders, helping to accelerate the development of critical installation experience and driving early volume production of charging units.

Finally, fleet operators could improve consumers’ perception of electric-drive vehicles by increasing their public exposure and facilitating interaction with a new technology. Urban parcel delivery vehicles display some of the most familiar brands in corporate America, and they are a common sight on city roads and highways across the United States. Typical consumers interact with utility and telecommunications service vehicles in their neighborhoods every day. Rental cars, taxi cabs and transit vehicles offer even greater exposure. By demonstrating the safety, reliability, and real world benefits of electric drive technologies, fleet operators can dramatically enhance consumers’ perceptions of HEVs, PHEVs, and EVs.

3 Million

Number of vehicles owned and managed by the top 10 fleet leasing companies.
CHAPTER 1.2

Fleet Demographics

Vehicle fleets are utilized by an extremely diverse set of industries and government agencies for an equally diverse set of purposes. Individual fleet sizes vary from less than five vehicles to as large as tens-of-thousands of vehicles.

Fleet vehicles operate in nearly all sectors of the economy and are important for a number of industry sectors. In 2009, corporate and commercial fleets in the private sector accounted the majority of fleet vehicles in operation (VIO), with a combined 74 percent market share (8.8 million and 3.2 million, respectively). Public sector fleets at the federal, state and local level accounted for the balance, with approximately 4.4 million VIO.

In terms of industry representation, short-haul delivery vehicles account for the largest share of U.S. fleet vehicles in operation, with 28 percent of the total market share. State and local government fleets are the second largest industry segment, representing nearly one-fourth of U.S. fleet vehicles in operation and the overwhelming majority of public sector vehicles. Passenger transportation applications such as rental cars, taxi fleets, school buses, and transit buses also account for a substantial share (16 percent of the total).

Fleet vehicles include the full spectrum of automotive sizes and weights, from passenger automobiles and light-duty trucks to medium- and heavy-duty trucks. In 2009, there were approximately 4.8 million automobiles and 4.3 million class 1-2 light-duty trucks in operation. Class 3 through 6 medium-duty trucks in operation totaled 2.6 million. Class 7 and 8 heavy-duty trucks in fleets totaled 3.9 million. Transit and school buses accounted for an additional 0.8 million fleet vehicles in operation. (See Figure IA for a breakdown of vehicle class by weight.)

What Constitutes A Fleet?

For the purposes of this report, a fleet is defined as five or more vehicles under central commercial or government ownership. Data has been aggregated from a number of sources, including the U.S. Department of Energy, Oak Ridge National Laboratory, R.L. Polk and Co., and industry publications such as Automotive Fleet. Data was also acquired from industry associations, fleet operators, vehicle OEMs, and other primary sources.

It is important to note that there are a variety of interpretations and definitions of fleets, and these impact the way that data is aggregated by different sources. Aggregating historical data series is particularly difficult as a result of changing definitions over time. The Department of Energy Annual Energy Outlook reports sales, stock, and energy consumption data for light-duty vehicles (cars and SUVs) in fleets of 10 or more only. In their annual Transportation Energy Data Book, Oak Ridge National Laboratory defines fleets as having 15 or more vehicles in operation or purchasing five or more vehicles annually. This definition also serves as the reporting criteria for prominent industry trade publications, including Automotive Fleet.

At least two important fleet demographics are not covered by these definitions, and they are not directly addressed by this analysis. First, smaller fleets of less than five vehicles, which may include as few as one or two vehicles in operation, are not included. Second, less structured arrangements that may have some fleet characteristics, but are not typically defined as fleets, are not included. An example would be an employer providing drivers with fuel reimbursement accounts.
Total fleet vehicles in operation totaled 16.3 million in 2009. The private sector accounted for nearly three-fourths of the total. Within the public sector, state and local government agencies accounted for 85 percent of the government total.

**Vehicles In Operation by Sector & Application**

- **Private Sector**: 12.4 million vehicles
- **Public Sector**: 3.9 million vehicles

**Fleet Demographics**

- **State & Local** (3.7 million), \(85\%\) of the total
- **Federal** (2.3 million), \(14\%\) of the total

**Vehicles In Operation by Application & Class**

**Short-Haul Delivery**

- Class 1-2: \(4.5\%\)
- Class 3: \(6\%\)
- Class 4: \(3\%\)
- Class 5: \(6\%\)
- Class 6: \(3\%\)
- Class 7: \(3\%\)
- Class 8: \(2.1\%\)

**Long-Haul Delivery**

- Class 3: \(6\%\)
- Class 4: \(1\%\)
- Class 5: \(6\%\)
- Class 6: \(1\%\)
- Class 7: \(45\%\)
- Class 8: \(1.7\%\)

**Sales & Service**

- Class 3: \(17\%\)
- Class 4: \(20\%\)
- Class 5: \(20\%\)
- Class 6: \(10\%\)
- Class 7: \(4\%\)
- Class 8: \(1\%\)

**Utility & Telecom**

- Class 1-2: \(500,000\)
- Class 3: \(150,000\)
- Class 4: \(450,000\)
- Class 5: \(650,000\)
- Class 6: \(1.7\ million\)

**Rental**

- Class 1-2: \(1.6\ million\)
- Class 3: \(4.5\ million\)
- Class 4: \(500,000\)
- Class 5: \(6\ million\)
- Class 6: \(2.1\ million\)

**Federal Vehicles**

- Class 1-2: \(450,000\)
- Class 3-5: \(1,000,000\)
- Class 6: \(2,100,000\)

**_SECTORS_**

- **Private Sector**: 12.4 million vehicles
- **Public Sector**: 3.9 million vehicles

**APPLICATIONS & CLASSES**

- **Short-Haul Delivery**: 16.3 million vehicles
- **Long-Haul Delivery**: 16.3 million vehicles
- **Sales & Service**: 17 million vehicles
- **Utility & Telecom**: 500,000 vehicles
- **Rental**: 1.6 million vehicles
- **Federal Vehicles**: 450,000 vehicles

**NOTE** Vehicle Applications are listed in order of market share; vehicle class domains vary in scale and are measured in thousands.
CHAPTER 1.3

Advantages of Fleet Operators

Commercial and government fleets possess a number of key advantages that could enable them to be early adopters of grid-enabled vehicles. These advantages include the way fleet managers make vehicle acquisition decisions as well as certain unique operational traits of fleets.

As policymakers and industry participants consider options for accelerating the development and deployment of grid-enabled vehicles, it will be important to target a broad market. While high levels of adoption among personal-use passenger vehicles is the key to meaningfully improving American energy security, commercial and government fleet vehicles can help drive early volume ramp-up in battery manufacturing and vehicle component supply chains. These scale effects could ultimately benefit the broader consumer market through reduced costs.

For a number of reasons, grid-enabled vehicles should be an attractive option for fleet owners in the very near-term. Perhaps most important, the decision-making process for purchasing a vehicle is significantly different as compared to that for personal-use passenger vehicles. While consumers often focus on vehicle aesthetics, performance, and style, most fleet operators focus heavily on the life-cycle economics of an acquisition. The lower operating and maintenance costs of PHEVs and EVs should provide clear value to fleet owners, particularly in higher mileage applications and in cases where upfront costs can be offset by longer battery life, extended ownership periods, lighter-weight vehicle components, and innovative business models.

Fleet owners may also be more prepared to address the infrastructure challenges that industry observers assume will present obstacles to consumers. For fleets that centrally park, single-point installation and the ability to charge multiple vehicles per charger will provide economies of scale. Highly predictable routing will minimize the need for public charging infrastructure for EVs and PHEVs. This could be particularly true in cases where daily miles traveled are low. In contrast, the successful deployment of grid-enabled electric drive passenger vehicles in the consumer market may require a substantial investment in public (shared) charging infrastructure, regardless of whether this infrastructure is highly utilized or not.

Total Cost of Ownership Approach to Acquisition
When asked, fleet managers rank total cost of vehicle ownership as the most significant factor driving acquisition decisions. Consumers, on the other hand, may purchase for a variety of reasons, including aesthetics and style, in addition to cost. If electric drive technologies can be proven to reduce total vehicle ownership costs while also allowing vehicle drivers to successfully accomplish their primary objectives, fleet managers may be willing to adopt electric drive vehicles sooner than typical consumers.

Route Predictability
The most cost-intensive component in current-generation electric drive vehicles is the battery. Assuming a battery cost of $600 per kWh (industry-wide 2010 average),8 battery packs for high-duty electric drive vehicles can range from $1,200 to nearly $20,000 depending on drivetrain configuration. In heavy truck applications, pure EV batteries can cost as much as $48,000. However, in cases where fleet vehicles have highly predictable routes with little variation from day to day, batteries can be right-sized to minimize excess capacity, reducing upfront investment in unneeded energy storage.

High Vehicle Utilization Rates
Fleet vehicles typically have higher utilization rates than consumer vehicles. Given the significantly lower fuel and maintenance costs associated with electric drive technologies, increased utilization spreads high battery costs across a higher volume of lower-cost miles, increasing the return on investment. The result may be that fleet operators can more quickly recoup the higher upfront costs of electric drive vehicles.

Use of Central Parking Facilities
Fleets that make use of central parking depots may be able to avoid dependence on public charging infrastructure for EVs and PHEVs. This could be particularly true in cases where daily miles traveled are low. In contrast, the successful deployment of grid-enabled electric drive passenger vehicles in the consumer market may require a substantial investment in public (shared) charging infrastructure, regardless of whether this infrastructure is highly utilized or not.

Importance of Maintenance and Service Costs
The maintenance and service costs for certain electric drive vehicles may be far lower over the life of the vehicle than the costs associated with internal combustion engine vehicles. Due to the simplicity of their design, EVs are expected to have the lowest routine maintenance and service costs of any electric drive technology, though PHEVs and HEVs will also offer savings. Particularly in fleet applications that operate vehicles for longer periods of time or into high mileage ranges, electric drive vehicles may represent a substantial cost offset.

Lower Electricity Rates
The electricity rates paid by commercial and industrial consumers—those most likely to make use of electric drive technology—from are often significantly less than those paid by residential consumers. The fuel cost per mile traveled is one of the key economic factors differentiating plug-in electric drive vehicles from other technologies, and commercial and industrial rate payers are likely to benefit even more than typical consumers due to lower rates.

Alternative Business Models
Fleet managers may benefit from alternative business models that can help facilitate adoption of electric drive technology. From a financing perspective, commercial leasing operations in the United States adhere to different norms than the passenger vehicle market, and the risks associated with battery residuals may be different. Fleets may also have access to a broader set of highly routinized drivers. For example, rental car companies could target EVs toward urban customer segments with the driving characteristics required to make EV adoption a success.

Corporate Sustainability Initiatives
In addition to the economic and operational advantages of fleets and fleet operators, commercial and government enterprises may consider electric drive vehicles in the context of corporate sustainability initiatives. The reduced emissions of electric drive vehicles may help companies meet carbon mitigation goals, and a number of corporate and government enterprises have also committed to using less petroleum. Electric drive vehicles can facilitate progress toward these goals.
Total Cost of Ownership Approach to Acquisition

Compared to typical consumers in the passenger vehicle market, fleet operators may be more likely to take a total cost of ownership (TCO) view when evaluating various vehicle technologies. If electric drive technologies meet the mission needs of a given fleet and can reliably demonstrate a return on investment compared to an internal combustion engine vehicle, fleet operators with an eye on the bottom line should be willing to invest in efficiency. Comparatively, individual passenger vehicle consumers may evaluate a vehicle purchase based on much less tangible vehicle characteristics, including personal taste, aesthetics, and performance features that they rarely fully utilize, such as 4-wheel drive.

When asked, fleet operators rank total cost of vehicle ownership as the most significant factor driving acquisition decisions. In one recent survey of fleet owners across multiple fleet segments, 61 percent of respondents indicated that cost of ownership across the service life of the vehicle is the normal way that they compare vehicles with respect to cost when making purchasing or leasing decisions. Just 18 percent of respondents indicated that the basic purchase price was the main factor. Within total cost, the survey found that fleet operators rank acquisition cost as their first priority must often, fuel economy or fuel costs as their second priority, and other operating costs as their third priority.10

Understanding TCO
A vehicle’s total cost of ownership represents the sum of the capital and operating costs associated with ownership. In other words, TCO equals the fully-burdened cost of purchasing, refueling, and maintaining a vehicle over the entire ownership period. For gasoline- and diesel-powered vehicles, TCO components would include the purchase price, the cost of fuel, routine maintenance costs (oil changes, engine upkeep, etc.), and any more significant repair costs (engine replacement, etc.) incurred by the owner.

For electric-drive technologies, the TCO equation is slightly more expansive. A typical EV owner would incur an initial capital outlay, plus electricity costs, maintenance costs, and the cost of purchasing charging infrastructure. EV owners might also expect to incur costs associated with the IT backbone that will manage the interface between vehicles and utilities. This cost could be incorporated into the price of electricity or it could appear as a user fee for access to a charging network. Two additional factors impact the TCO of both traditional gasoline vehicles and electric-drive vehicles:

Residual Value and TCO
Many owners do not maintain possession of a vehicle for its entire useful life. Many times, an owner will seek to sell or trade in a vehicle well before it reaches its full operational capacity. The residual value of a vehicle can have a significant impact on the total cost of ownership. Today, the used car market for internal combustion engine vehicles is well-defined and mature. Consumers can easily obtain the blue book value of a vehicle, which can serve as a minimum baseline. The condition of the vehicle and the demand in a given market for certain features (horsepower, hauling capacity, efficiency, etc.) can raise or lower the residual value of an ICE vehicle.

The picture for electric drive technologies is somewhat different. In particular, the residual value of PHEVs and EVs is clouded by the lack of certainty regarding battery performance after large-format lithium-ion batteries exceed their usefulness in automotive applications. Given the current costs for both EV and PHEV batteries, the absence of an assumed residual value will substantially decrease the economic proposition of the vehicle. Conversely, the possibility of a meaningful value assigned to a used large-format automotive battery could sharply increase its economic attractiveness.

Ownership Structure and TCO
A second variable factor that impacts total cost of ownership is the manner in which a vehicle is financed. In the simplest case, a vehicle could be paid for in its entirety upfront with cash. In this instance, the vehicle would have no additional costs related to capital financing over its lifetime. More commonly, vehicles may be purchased through some combination of a down payment and a loan; or a vehicle may be leased, also requiring upfront capital. Each of these ownership models present the customer with a different value proposition. Cash ownership or a high down payment and a loan will minimize the financing costs incurred over the ownership period. Vehicle leasing minimizes the amount of upfront capital associated with vehicle ownership. In exchange, the customer agrees to pay finance charges on top of monthly payments that include a depreciation cost for the capital value of the battery.

There are two common arrangements for vehicle ownership in fleets. The first is direct company or institutional ownership. In this case, a given organization may choose to purchase, service, and maintain its fleet vehicles on its own. This is the most common form of fleet vehicle ownership. As of January 2010, 80 percent of the cars and class-1-5 trucks in fleets of 15 or more were company/institutionally owned in the United States.13 The most common alternative to outright ownership is some form of vehicle leasing. As of January 2010, approximately 20 percent of the cars and class-1-5 trucks in fleets of 15 or more were leased or managed by a third party.14 The 10 largest fleet lessors managed nearly 3 million cars and trucks in U.S. fleets in 2009.14

11 Id.
12 Busby Publishing Company, APR 2010 at 9
13 Id.
14 Id. at 66
The lithium-ion batteries that will power the first generation of EVs and PHEVs to enter the marketplace may be over-sized for the needs of typical consumers in the passenger market. For example, an electric vehicle with a charge-depleting range of 100 miles far exceeds the average daily miles traveled of individual U.S. drivers in any region. At 36.9 miles, average daily driving distance is highest for rural drivers, but still low enough to comfortably operate in charge-depleting mode of a PHEV-40 and simply charge at home at night. Of course, such statistics do not account for multiple drivers in a household operating a vehicle each day, but even then, average daily mileage totals are well below 100 miles.

Figure 1F presents the average daily miles driven per vehicle in households ranging from those that own a single vehicle up to those that own six. Even accounting for multiple drivers, the vast majority of vehicles travel less than 30 miles per day on average. And yet, the first commercially available EVs and PHEVs will provide consumers with charge-depleting drive ranges that essentially start at 40 miles (though the range may be somewhat lower depending on the route traveled and ambient air temperature). Allowing for the fact that averages often cloak significant variances, and that individual drivers may often choose to travel distances in excess of the charge-depleting range of their PHEV or EV. In essence, today’s EVs and PHEVs are being designed to provide for consumers’ longest expected trips, even if those trips rarely occur. Ultimately, this is clearly necessary; consumers do not purchase vehicles based on ‘average’ needs.

However, the need to oversize batteries for the consumer market is a key driver of vehicle cost. At today’s industry average prices, a 24 kilowatt hour (kWh) battery providing 100 miles of range could add as much as $14,400 to the cost of a vehicle for the battery alone—33 percent of the total vehicle cost. In contrast, a fleet operator with a high degree of route predictability may have a specified set of daily customers. The routes traveled are well known in advance and recur each day. Transit and school buses are another example of fleets with highly routinized travel patterns. In other applications, such as a commercial parcel delivery fleet, the routes may not be perfectly predictable, but an individual driver may have a handful of large, consistent deliveries (commercial office buildings, for example) plus some additional less predictable stops within an established service territory. This high degree of daily mileage predictability should also contribute to battery right-sizing.

One important question regarding battery right-sizing is the degree to which battery manufacturers can be flexible in designing batteries customized for various mileage ranges. In fact, a number of battery OEMs report that this kind of flexibility is relatively straightforward. Once battery cells are manufactured and installed into module units, packs of varying sizes can be assembled. Of course, larger purchase orders would likely make the economics of right-sizing batteries more compelling for battery makers.

Ultimately, route predictability may be among the more important characteristics that could facilitate the uptake of grid-enabled vehicles in fleet applications. In addition to reducing upfront costs, high levels of route predictability would reduce fleet operators’ dependence on public charging infrastructure by allowing grid-enabled vehicles to be matched with the behaviors that are most conducive to their use. Whereas a consumer might average 30 miles driven per day, variance from this average could necessitate significant investment in public charging infrastructure, cause range anxiety, or relegate early EVs and PHEVs to secondary-use status. As a consumer’s second automobile, the utilization rates of these EVs and PHEVs may be low, and payback periods may therefore be long.

In contrast, a fleet operator with a high degree of route predictability can employ GEVs in relatively high utilization applications with minimal risk. To the extent that public charging is required at all, investment can be highly targeted and focused.

**FIGURE 1F**

<table>
<thead>
<tr>
<th>Battery Cost as a Percent of Vehicle Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIVEetrain</strong></td>
</tr>
<tr>
<td>PHEV</td>
</tr>
<tr>
<td>EV</td>
</tr>
<tr>
<td>PHEV</td>
</tr>
<tr>
<td>EV</td>
</tr>
</tbody>
</table>

Source: Interviews, Published Vehicle Specs, PRTM Estimates

**FIGURE 1G**

<table>
<thead>
<tr>
<th>DRIVETRAIN CLASS</th>
<th>KWH</th>
<th>S/KWH</th>
<th>BATTERY COST</th>
<th>VEHICLE COST</th>
<th>BATTERY % OF VEHICLE COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHEV Auto</td>
<td>12</td>
<td>660</td>
<td>$14,400</td>
<td>$36,000</td>
<td>39</td>
</tr>
<tr>
<td>EV Auto</td>
<td>17</td>
<td>1,800</td>
<td>$35,400</td>
<td>$70,000</td>
<td>36</td>
</tr>
<tr>
<td>PHEV Class 4</td>
<td>29</td>
<td>1,200</td>
<td>$36,000</td>
<td>$103,000</td>
<td>35</td>
</tr>
<tr>
<td>EV Class 4</td>
<td>65</td>
<td>7,200</td>
<td>$288,000</td>
<td>$700,000</td>
<td>41</td>
</tr>
</tbody>
</table>

Source: DOE, ORNL, Transportation Energy Data Book
High Vehicle Utilization Rates

A vehicle’s utilization rate is essentially the number of miles traveled over a given period of time, though there are important exceptions. For example, utility and telecom service vehicles may run the engine and consume fuel, but do not perform certain auxiliary functions. These functions may make such vehicles strong candidates for electrification. Still, the most straightforward measure of vehicle utilization is annual miles traveled.

In general, commercial and corporate fleet vehicles tend to have higher annual miles traveled than passenger vehicles in the consumer market. Recently released survey data suggests that household vehicles travel between 7,500 and 12,800 miles per year, depending on the age of the vehicles themselves.

In contrast, the average annual miles traveled for similarly-sized vehicles in a corporate fleet application are typically much higher. Data taken from a 2008 survey of business fleet operators suggests that average annual miles traveled can range as high as 28,020 miles for certain light-truck applications. The average was closer to 20,000 miles for passenger cars.

Ultimately, however, high utilization rates present both opportunities and challenges for electric vehicle technology. High utilization provides the most direct metric for accelerating the efficiency payback on an electric drive vehicle with a high upfront capital premium and low operating costs compared to an ICE vehicle. At the same time, vehicles with extremely high utilization rates may not be able to rest for the several hours needed to charge depleted batteries. Perhaps of greater importance, battery electric vehicles with extremely high utilization rates could require charging multiple times throughout the day, and therefore need access to multiple charge points.

In the case of a business fleet vehicle with 28,000 miles of annual travel, daily miles traveled could easily exceed 100 if weekend travel is fully excluded. This could necessitate an alternative charging technology, such as battery swapping or fast charging, or it could make these fleets more likely to adopt an HEV/PHEV versus an EV.

In urban markets, high utilization rates tend to have high replacement cycles, though there are important exceptions for, example, a company or institution that owns its fleet vehicles may choose to hold on to them for the full life of the vehicle, 10 years or more, regardless of utilization. This could be advantageous if the vehicle is highly specialized and unlikely to be prominent in the marketplace. Nonetheless, highly utilized vehicles tend to approach service milestones more quickly and operators often prefer to sell these vehicles before incurring those costs.

Fleet survey data suggests that average months in service for light-duty vehicles in a corporate fleet application are far below the norms for consumer vehicles (just as utilization rates are far higher). In 2008, the median consumer vehicle lifespan was 9.4 years for an automobile and 7.5 years for a light truck. In contrast, compact cars averaged three years in service in business fleet applications while intermediate cars averaged 4.2 years. Light trucks averaged slightly higher at 4.25 years.

Conditions in the broader economy can have a significant impact on the average age of fleet vehicles. During the 2007-2009 recession, average vehicle ages in service for service fleets of vehicles in operation increased by as much as 10 percent in certain asset classes. Operators that owned their vehicles strenuously avoided capital expenditures that could be postponed through increased maintenance. With vehicle resale values at low levels, operators in commercial lease agreements simply held onto vehicles for longer periods.

One potential benefit of a shorter replacement cycle is the ability of fleet managers to maintain access to up-to-date technology. In the passenger market, consumers that hold onto vehicles for an average of seven to 10 years could end up driving vehicles based on obsolete battery technology. This is exacerbated by the length of vehicle warranties, which are currently centered on eight to 10 years and 100,000 miles or more. Some OEMs may establish business models that allow for battery upgrades over time, but this has not occurred yet. In the fleet market, an operator cycling through vehicles every four years will likely have rolling access to the best batteries.

Rental companies are an example of a fleet industry segment that tends to have high turnover rates, making it a potentially attractive option for accelerating the deployment of electric drive technologies. Because the average rental fleet acquires new vehicles as often as every six to 10 months, the opportunity may exist to establish a pipeline of frequent orders for electric drive vehicles.

Some rental and car share companies also target extremely high utilization rates. In the case of car sharing, it is typically optimal to minimize vehicle downtime throughout the day, which would allow only for a short charge period overnight. Daytime car sharing customers may not mind a quick stop at the gas station, but they will be unwilling to charge a vehicle for the several hours required by Level II electric vehicle supply equipment (XVSE). Here again, access to fast charge or battery swap would be needed. In addition, car sharing companies report that they would need the ability to remotely monitor battery state of charge in order to consider EVs and PHEVs, a capability not yet embraced by vehicle OEMs.
Use of Central Parking Facilities

Some fleets may also benefit from the ability to bypass a handful of the more challenging issues surrounding infrastructure for grid-enabled vehicles. PHEVs and EVs charge their batteries by connecting to the electricity grid. The type of connection and the infrastructure required to support it can vary significantly, directly impacting charge times, cost, and convenience. Moreover, a significant amount of uncertainty still exists regarding certain key issues, including the amount and type of charging infrastructure needed; the business model that will support the construction of charging infrastructure; and the critical functions that will need to be embedded in charge points in order to harmonize the interaction of plug-in vehicles with the electric power sector.

Private Charging Infrastructure

The vast majority of EV and PHEV consumers in the passenger market will charge their vehicles at a dedicated parking spot. In many cases, this will occur in a private garage or carport, to which more than half of city-dwellers and two-thirds of other U.S. drivers have access. Some additional portion of private consumers may have access to permitted street parking or other dedicated locations.

Some other dedicated location on a routine basis, though uncertainties exist in this area. For many drivers, the workplace will also represent an opportunity to access a dedicated charge spot. In some cases, this will be a Level II charging unit installed in a corporate parking lot. An alternative scenario could be a rented parking spot in a public parking garage, familiar to most urban commuters. Recent analysis suggests that as much as 90 percent of PHEV and EV driver charging needs can be met by providing a dedicated charging opportunity at home and the workplace.²⁶ For homes that lack a dedicated parking space, the market has yet to determine how best to ensure access to overnight EVSE.

Private Charging Infrastructure

Charging Infrastructure: Terms of Service

<table>
<thead>
<tr>
<th>CHARGER</th>
<th>APPLICATIONS</th>
<th>OUTLET STYLE</th>
<th>VOLTAGE</th>
<th>AMPERAGE</th>
<th>COST</th>
<th>EV CHARGE TIME</th>
<th>PHEV CHARGE TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level One</td>
<td>Private</td>
<td>Standard U.S. Outlet</td>
<td>120v</td>
<td>15A</td>
<td>Basic Level II</td>
<td>10-12 hours</td>
<td>15-18 hours</td>
</tr>
<tr>
<td>Level Two</td>
<td>Private</td>
<td>Standard U.S. Outlet</td>
<td>220-240v</td>
<td>15-50A</td>
<td>$200-$400</td>
<td>24-30 hours</td>
<td>3-4 hrs</td>
</tr>
<tr>
<td>Level Three</td>
<td>Private</td>
<td>Industrial</td>
<td>220-240v</td>
<td>50-80A</td>
<td>$1,000-$2,000</td>
<td>5-8 hrs</td>
<td>1-2 hrs</td>
</tr>
</tbody>
</table>


an expensive battery by defraying it over time with comparatively cheap electricity. This essentially places an upper limit on what consumers will be willing to pay for public charging.

A single EVSE charging at 3.3 kW per hour could in theory provide nearly 80 kWh of electricity per day (or 29,200 kWh per year) to a plug-in electric vehicle. Given that most chargers will not be used continuously, however, the true amount is likely to be considerably lower. Retail electricity prices in the United States vary substantially by region, but the national average is approximately 10 cents per kWh (as of June 2010). If operators were to charge a premium of 20 percent, they would receive revenues (less overhead) of just $289 per year. For average fleet operators this translates to a marginal increase in operating costs of $3,500, the payback period would be six years—but this assumes continuous (and unrealistic) use of the charge point.

With that said, the assumption that most chargers will not be used continuously, how-ever, the true amount is likely to be considerably lower. Retail electricity prices in the United States vary substantially by region, but the national average is approximately 10 cents per kWh (as of June 2010). If operators were to charge a premium of 20 percent, they would receive revenues (less overhead) of just $289 per year. For average fleet operators this translates to a marginal increase in operating costs of $3,500, the payback period would be six years—but this assumes continuous (and unrealistic) use of the charge point. 

Fleet Charging Behavior

The issues affecting deployment of private and public charging infrastructure in the consumer market may be of significantly less concern for a number of fleet applications, allowing them to more confidently move forward in adopting grid-enabled vehicle technology. In part, this is because a substantial portion of fleet vehicles are centrally parked, centrally refueled, or both. The ability to access a central hub could allow for single-point installation of multiple charge points serving multiple vehicles, providing clear efficiencies in electrical equipment upgrades. In conjunction with predictable routing or predictable daily miles traveled, centralized parking could allow PHEVs and EVs operating in fleets to maximize electric miles traveled without the need to depend on public charging infrastructure.

According to data accumulated by the U.S. Department of Commerce, 43.9 percent of trucks in fleets of six or more refuel at their own facility. The practice of central refueling tends to be most common in larger fleets, with nearly 50 percent of fleets sized 11 to 50 refueling at their own facility. Predictable routing—or at least a consistent service territory—could also play an important role in minimizing infrastructure requirements for fleets. In fleet applications where daily miles traveled are consistently low, range anxiety will be an issue of minor importance, and the need for public chargers will be minimal to nonexistent. In applications where miles traveled are higher, but routing is predictable, siting public chargers should be straightforward. Refueling behavior is likely to be one of the more important operational characteristics for determining the viability of plug-in electric drive vehicles in fleet applications. The issue is less of an operational constraint for PHEVs, though an accessible infrastructure could enable a higher fraction of charge-depleting miles versus charge-sustaining miles. For EVs, refueling behavior will be of critical importance, while it matters least for HEVs.

Importance of Maintenance and Service Costs

Maintenance and service costs represent a significant portion of the operating budget of most fleet managers today. ICE vehicles require a number of regularly scheduled services as well as maintenance and replacement costs at key mileage milestones. Regularly scheduled service events could include oil changes and other fluid service, such as transmission and brake fluid. As vehicle age increases in terms of miles, repair and replacement costs rise for items such as transmissions, brake pads, engine components, and ultimately the engine itself.

While all of this is no doubt true for vehicles owned by typical consumers, fleet operators are likely to be more acutely aware of the costs over time. As internal combustion engine vehicles reach certain mileage tipping points, maintenance service can rise to as much as 20 to 30 percent of annual operating costs in certain vehicle applications. For fleet managers, this is a significant expense. In fact, fleet operators tend to sell vehicles in advance of certain mileage milestones or in advance of warranty expiration in order to avoid incurring the maintenance costs—though the cost may ultimately be paid in reduced residual value.

The maintenance and repair costs of electric drive vehicles are likely to be significantly less than those associated with traditional internal combustion engine vehicles. This is a result of the fact that electric-drive systems tend to have fewer moving parts and wear items than internal combustion engines. The maintenance savings are most significant for EVs, which are based on the simplest design. PHEVs that tend to operate in charge-depleting mode can also have sharply reduced maintenance costs. The benefit is least significant for HEVs.
Lower Electricity Rates

The low—and stable—cost of electricity compared to the relatively high cost of gasoline is a primary driver of the economic benefits of grid-enabled vehicles. Highly efficient electric motors coupled with low electricity prices result in EV and PHEV fuel costs that are as little as 25 percent the cost associated with a highly efficient internal combustion engine vehicle. And while all consumers will benefit from this dynamic, the typical fleet operator may have an additional advantage.

The average retail electricity price paid by all U.S. consumers was 9 cents per kWh in 2009 (real $2005). However, there is substantial price variation across different end-use sectors of the economy. Residential consumers currently pay the highest rates, averaging 10.5 cents per kWh in 2009. In contrast, commercial and industrial users pay the lowest rates, averaging 9.3 and 6.2 cents per kWh, respectively. For commercial and corporate fleet operators, the likelihood that they will have access to these lower rates significantly improves the economics of PHEV and EV ownership for a given vehicle size.

In terms of total cost economics for grid-enabled vehicles, electricity prices can have an important impact—though ultimately gasoline prices, vehicle utilization rates, and battery costs are likely to have a more significant impact. Still, in a light-duty automobile fleet application traveling 17,500 miles per year, the difference between residential and industrial electricity prices equates to an approximate one year improvement in the payback period of an EV compared to a 30 mpg ICE vehicle with gasoline at $3.00 per gallon.

An additional factor assisting fleet operators may be utilities’ desire to manage the relatively large loads that will be associated with clustered charging. In the case of a fleet of EVs or PHEVs charging at a central depot, simultaneous charging of numerous vehicles could create a reliability issue for the local distribution network. Therefore, utilities may provide strong financial incentives for fleet operators to charge during off-peak hours.

In pilot programs today, PHEV and EV drivers accessing residential electricity to charge their vehicles receive rate discounts of 50 percent or more during off-peak hours. While similar programs for commercial and industrial rate-payers are not yet widespread, it will be just as important—if not more so—to incentivize fleet GREV customers to charge off peak. In part, this goal can be met through the establishment of comparatively high peak power rates. Utilities will also likely work closely with large fleets to install charge management functionality that can be employed if needed. Off-peak discounts may simply provide an additional price incentive.

Alternative Business Models

The norms surrounding vehicle financing and acquisition in the commercial fleet industry are significantly different than those in the passenger vehicle market. This is particularly true for light-duty vehicles, but also applies to a significant portion of medium-duty trucks.

In a conventional lease agreement, an upfront down payment is accompanied by fixed monthly payments over a predetermined time period, number of miles, or both. At the end of the lease period, the lessor returns the vehicle to the lessee, who is then responsible for selling or releasing the used vehicle. In other words, the lessor holds the risk of recovering some amount of residual value from the vehicle. In fleet applications, this type of ‘closed-end’ leasing is not the norm, however, accounting for less than 10 percent of commercial lease transactions in automobiles and class 1-5 trucks.

In the United States, the standard commercial lease agreement is a terminal rental adjustment clause (TRAC) lease, or open-ended lease model. In this model, the term of the lease is left open-ended and to the customer’s discretion. Generally a one-year minimum applies with monthly renewals thereafter. However, when the customer is prepared to end the lease, they assume responsibility for the vehicle’s resale value. If the vehicle sells for an amount that is greater than the balance of the undepreciated lease value, the lessee earns a return. If the vehicle sells for less than the undepreciated lease value, the lessee must pay the difference. This approach gives the vehicle operator a stronger incentive to keep the vehicle in good condition in order to maximize its value in the used vehicle market.

Figure 18 demonstrates the net result of TRAC lease release for an individual vehicle in three cases. If the net proceeds (upon asset sale) exceed book value, the lessee (or fleet operator, in this case) receives the excess back as a refund of previously paid rentals. If the net proceeds are less than book value, the difference is paid as additional rentals.

Under current lease accounting guidelines, a TRAC lease may be treated as an operating or capital lease. Moreover, there are generally no excess-mileage or wear-and-tear restrictions (vs. traditional ‘closed-end’ leasing models). In effect, the TRAC lease provides similar flexibility to ownership, but allows the fleet operator to balance the increased capital cost with lower operating costs to best realize the total life-cycle cost savings.

Other Emerging Models

Due to their larger purchasing power, access to capital, and ability to structure financial packages with other participants in the electric drive vehicle industry, fleet operators may also benefit from the ability to leverage a number of emerging alternative business models in the electric vehicle industry. These models may impact the way fleet operators own and finance batteries and infrastructure as well as their ability to match EV capabilities with appropriate drive patterns.

Paying by the Mile

The low cost and relative stability of electricity prices provide drivers of EVs and PHEVs with a fairly high degree of certainty regarding fuel cost over time. This is in stark contrast to vehicles fueled by petroleum, which are subject to the high volatility of gasoline and diesel
prices. In the case of commercial and industrial enterprises that run fleets as part of core business functions, this volatility can cause significant budgeting and cost management challenges.

This volatility is often difficult to plan for, it is the result of complex dynamics in the upstream global oil market and downstream refining industry, as well as federal, state, and local tax policy. Recent history provides a case in point. After steadily rising between 2003 and 2007—and ultimately surging to record highs in mid-2008—crude oil and refined product prices crashed in late 2008 and early 2009. Today, while crude oil prices have regained significant strength to average between $75 and $85 per barrel, gasoline and diesel prices are somewhat below what might be expected. This is largely the result of weak domestic demand in the United States.41

In cases where EVs or PHEVs would meet their mission requirements, fleet operators may be willing to hedge against petroleum fuel price volatility through electrification. One way to do this would be to package the high cost of batteries with the low cost of electricity in a service contract similar to cellular phone packages offered by telecommunications companies today. Instead of purchasing a monthly “minutes” package, a fleet operator could purchase a monthly “miles” package. The cost per mile could include the value of the battery, charging equipment, and electricity. In the United States today, the cost of such a package might be very near to the cost of gasoline per mile—perhaps even slightly more. However, an operator that locked into such a contract would be able to confidently plan for fleet operational costs over time. In fact, for fleet applications that have a high degree of confidence in the number of miles traveled per vehicle per day, this model could provide near certainty in budgeting operational costs. In an era of highly volatile gasoline and diesel prices, that is likely to be an extremely valuable benefit of electrification.

Infrastructure Bundling

Just as the high capital cost of batteries can be offset through vehicle leasing, there should be nothing to prevent the cost of infrastructure from being financed over time. This is certainly true in the passenger vehicle market, where a number of providers have announced plans to provide access to home and/or other charging facilities for a monthly fee. However, infrastructure financing could have important ramifications for fleet operators that may need to purchase a significant number of chargers to support multiple vehicles.

One option for infrastructure financing may be to include it as part of energy efficient building retrofits. A number of market participants have emerged in recent years offering to finance the upfront costs of improving building energy efficiency in exchange for a portion of the associated cost savings over time. When implemented successfully, the result is a more efficient building that generates lower heating, ventilation, and air-conditioning bills—all while guaranteeing a revenue stream to the service provider. Efficiency improvements may also allow commercial facilities to qualify for higher environmental certifications in programs like the Leadership in Energy and Environmental Design (LEED) program.

The inclusion of vehicle charging units in building retrofits could be a low capital cost, low-risk opportunity for commercial and industrial entities to support their use of EVs and PHEVs. However, other possibilities exist for financing fleet infrastructure at commercial and industrial locations. In particular, local utilities may see vehicle charging as an opportunity to sell more power, and therefore may develop business models around providing fleet operators with access to chargers for a monthly fee.

Conversions

For some fleet operators that are able to hold onto vehicles for an extended period of time, drivetrain conversions may provide a relatively lower cost option for utilizing PHEV or EV technology. A conversion simply replaces the existing ICE powertrain with a new EV or PHEV powertrain, the rest of the vehicle is retained. Therefore, conversions are likely to be most appropriate for heavily depreciated assets.

PHEV or EV conversions could fit within the operational norm for some companies today. For example, in certain service applications, calendar lifespan of a typical vehicle can be in excess of eight to 10 years. In instances where these vehicles also log high miles—waste removal trucks, for example—fleet operators today sometimes opt for a drivetrain replacement rather than incurring the cost of purchasing a new vehicle. A number of companies today are marketing PHEV or EV drivetrains as standalone products for both consumer and commercial conversions. While the consumer market may have potential, the value that many drivers place on vehicle appearance and age may limit the size of the overall conversion market. However, in fleet applications that derive utility from maximizing the operational lifespan of a vehicle, PHEV and EV powertrain conversions could represent a significant cost savings. The marginal cost of an electric drivetrain compared to an ICE drivetrain is likely to be less than the marginal cost of replacing a complete ICE vehicle with an electric drive vehicle. Yet the fuel savings-potential of GEV conversion is essentially the same as a new asset. Fleet operators who opt for conversions will have a smaller upfront investment to pay back, but will benefit from the same operational cost savings as operators who purchase their vehicles new.

41 EIA, Petroleum Imports, available at http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=HOFTc&f=M.
42 Morning Zets, “Credit Suisse: Down on Weak Demand; Rising Gasoline Inventories,” Bloomberg, September 26, 2010.
Corporate Sustainability Initiatives

Corporate sustainability initiatives aim to incorporate a more proactive stance on social and community issues into an organization’s core business functions. In addition to improving brand identity with customers and business partners, investments in sustainability programs have also been found to boost employee satisfaction, retention and loyalty.44 While in the past, corporate sustainability was often viewed with skepticism as an attempt by firms to prove their “green credentials,” it is now becoming an increasingly important part of corporate strategy. In addition to improving brand value, sustainability initiatives can reduce costs and drive improved financial performance. As a result, corporations and governments are investing substantial sums in sustainability initiatives. In 2010, the U.S. sustainable business market is estimated to be worth $27.6 billion.45

For a number of firms and government agencies, adopting HEVs, PHEVs or EVs is fast becoming a crucial component of both cost saving and sustainability strategies. Coca-Cola for example, considered the world’s most valuable brand at over $70 billion, had deployed more than 300 diesel-electric hybrid trucks by the end of 2009 as part of its efforts to use more fuel-efficient modes of delivery.46 Others major firms, including UPS and FedEx, have all begun using standard HEVs for delivery purposes in recent years.47 Enterprise Rent-A-Car is set to add 500 Nissan Leafs to its rental fleet. Hertz is planning to roll out a similar GEV rental and car-sharing program in 2011.48 In addition, some firms and government agencies are already moving to incorporate EVs and PHEVs into their vehicle fleet. In September 2010, the PepsiCo subsidiary Prito-Lay announced that it would introduce 21 Smith Electric Newton delivery trucks this year to be followed by an additional 150 Smith EVs in 2011.49 These trucks, traveling up to 100 miles on a single charge, will serve the metropolitan areas of New York, NY; Columbus, OH, and Fort Worth TX. The vehicles will be centrally recharged at distribution centers.50 General Electric Co. recently announced the purchase of any major corporation—25,000 grid-enabled vehicles that will be integrated into their sales fleet over the next five years, accounting for approximately 50 percent of their total fleet of sales vehicles. The first vehicles purchased by GE will include 12,000 Chevy Volt PHEVs.

In part, corporate goals related to petroleum reduction and greenhouse gas abatement are playing a role in the early decision-making process of these fleet owners. However, the shift from petroleum-powered vehicles to electricity-powered vehicles also offers an improve- ment in a company’s operating model, brand-imaging, and bottom line financial performance in many cases. In addition, GEV sustainability initiatives reduce a company’s exposure to volatile fuel prices. Unlike internal sustainability initiatives, which firms must promote with expensive marketing campaigns, GEVs are their own uniquely visible advertisements—a persistent and convincing demonstration of their commitment to sustain- able business practices—that serve a critical oper- ating function. The benefit they bring to the company brand image is almost certainly positive.

In addition to taking advantage of lower operating and maintenance costs and strengthening brand image as technologically advanced, environmentally-conscious firms, these moves have the added benefit of spilling over into the consumer realm (and aiding the transition to GEVs more broadly) by enabling drivers to test and experience the technology before buying or leasing a vehicle of their own.

It is important to note that today’s sustainability ini- tiatives are about much more than brand enhancement and corporate “greenwashing.” The decision-making pro- cess that companies are using to evaluate EV and PHEV purchases offers perspective on their goals. For example, Johnson Controls Building Efficiency reports having utilized a three-step process to determine the “sweet spot” for electrification in its fleet of 5,000 service vans. The process was designed to match the proper vehicle, battery and drivetrain technology to the corresponding payload requirements, drive cycles, and driver profiles, resulting in reduced lifecycle operating costs. By evalu- ating mission needs, drive patterns, and working closely with actual drivers, the company was able to identify a significant portion of its fleet that has the potential to be electric—as many as 370 vehicles.51

Finally, state and local governments have also recently signaled their commitment to incorporating electric drive technologies in fleet applications. In November 2010, Better Place announced a partnership with the San Francisco Metropolitan Transportation Commission and the Bay Area Air Quality Management District that will result in the deployment of more than 60 EV taxies to the region. The vehicles will be sup- ported by four battery swap stations.52 Numerous cities throughout the nation have also begun rolling out hybrid transit buses in fleets, and the federal government has mandated PHEV purchases by agencies when the tech- nology is cost-effective.

46 Id.
47 The Coca-Cola Company’s Transit Connect Electric vehicle in Chicago, Illinois.
50 Id.
PART TWO

Fleet Challenges

2.1 OVERVIEW

2.2 FLEET CHALLENGES

SCHOOL BUSES. Regular routes, frequent stops, and ample
downtime for charging between pickups and dropoffs help vehicles
like these achieve substantial savings from plug-in technology.
ABSTRACT

While commercial and government fleets do possess a number of important advantages that could facilitate their adoption of grid-enabled vehicles, they will also face challenges. Some of the fundamental cost and technology issues affecting personal-use consumers will also be problematic for fleets. Today’s high lithium-ion battery costs will limit the attractiveness of GEVs in some instances. High costs for drivetrain components and the need to invest in infrastructure will also impact the economics of GEVs.

Vehicle leasing and fleet owners’ access to capital may allow them to address these issues more easily than the typical consumer, but GEVs will also require many fleet owners to be flexible and adapt to new business and acquisition practices. In addition, vehicle electrification may present a set of unique challenges for fleet operators, requiring a combination of careful planning and targeted public policy support.

CHAPTER 2.1

Overview

Numerous advantages of commercial and government fleet owners should help to facilitate their adoption of grid-enabled vehicles. However, a number of challenges will require public policy support in the near term.

The original Electrification Roadmap identified four key challenges that could impact adoption of plug-in hybrid and electric vehicles among consumers in the personal-use automotive market. These challenges included:

1. The high cost of the vehicles themselves, driven largely by the batteries;
2. the lack of available public charging infrastructure;
3. the need to enable successful vehicle-utility interface; and
4. a lack of mainstream consumer acceptance of grid-enabled vehicles.

As outlined in Part One of the Fleet Electrification Roadmap, commercial and government fleet operators should be well-prepared to address a number of these challenges. By matching the proper vehicle, battery and drivetrain technology to required payload requirements, drive cycles, and usage profiles, fleet operators can minimize upfront investment costs. Total investment in public and private charging infrastructure can also be efficient and optimized. Perhaps most importantly, grid-enabled vehicles could appeal to a significant number of fleet operators more quickly than they will appeal to mainstream consumers in the personal-use auto market. In that case, fleet operators would account for significant early demand volumes in the development of the large-format battery industry in addition to catalyzing the ramp-up of electric drivetrain component supply chains.

Nonetheless, the basic structure of challenges inhibiting mainstream consumer adoption can be used to identify potential challenges and problem areas that may need to be addressed in order to help facilitate commercial and government fleet adoption of GEVs. The high costs of battery and vehicle drivetrain components are an obvious example. High costs for lithium-ion batteries will impact the economics of GEVs for fleets just as they will for consumers. In fact, because many of the electric drivetrain supply chains for medium- and heavy-duty trucks are particularly immature today, the first GEVs coming to market in these segments carry a price premium well above what would be expected based on a “should cost” analysis of analogous light-duty components.

While the need for public charging infrastructure is less of an issue for many fleets, it could be important for some applications. In particular, fleets that tend to have high daily miles traveled and high utilization rates—such as taxis or long-haul delivery vehicles—could be highly dependent on public charging infrastructure. In fact, the extremely high utilization rates of taxis could necessitate access to fast charging or battery swapping as a means to maintain high levels of operation. And while this may be appealing from a technical standpoint, the cost of such systems could be an issue. Moreover, integrating the charging of fleet vehicle batteries with the electric power sector could actually be more—not less—challenging than integrating typical consumer vehicles in some cases.

In addition to these challenges, commercial and government fleet operators will have to manage a set of unique challenges for fleet operators, requiring a combination of careful planning and targeted public policy support.
### Fleet Challenges

In addition to the higher upfront costs, GEVs may present challenges to fleet operators. Balancing increased capital spending with operational savings will require institutional flexibility. Meanwhile, addressing battery residual risk and the impact of clustered charging could require public policy innovation.

For commercial and government fleet operators seeking to incorporate EVs or PHEVs into their fleets, technology cost will be the most significant consideration. The batteries and charging infrastructure associated with grid-enabled vehicles will result in increased capital costs versus a comparable internal combustion engine vehicle. While it is true that the reduced fuel and operating costs of EVs and PHEVs can generate tangible economic benefits for fleet operators, the return on investment associated with grid-enabled vehicles will be evaluated against other productive uses of capital in most public and private institutions. For the vast majority of U.S. fleet vehicles that are traditionally purchased and operated, corporate competition for capital—or agency-wide competition in the public sector—may be a key factor constraining the uptake of GEVs.

Fleet operators’ ability to lease vehicles that meet their mission needs could alleviate capital cost issues by treating vehicle acquisition expense more like an operating cost. However, the open-ended lease agreements commonly used in the United States will present fleet operators with the bulk of the risk associated with battery residual value. As long as there is a lack of experience surrounding the residual value of large-format automotive batteries, resale values of PHEVs and EVs will be unclear. This dynamic could act to offset the capital management benefits associated with leasing.

Finally, fleet operators’ confidence in the mission-fit of GEVs will also impact the rate of adoption. If commercial and government entities are not confident in the reliability of the vehicles themselves, they will be unwilling to use them. External economic factors also play a role—how fossil fuel prices will reduce the pressure on operators to minimize cost through investments in efficiency.

While these challenges will impact the demand for PHEVs and EVs among fleet operators, the vehicles themselves will pose challenges to the utility grid once they are in service. Most importantly, clustered charging of fleet GEVs may require upgrades to the utility distribution system.

#### Technology Costs

Battery costs associated with the first commercially available electric drive vehicles will result in a substantial overall cost premium. Current battery technology is descending the cost curve as volumes increase, but some fleet applications may find it difficult to realize a return on investment in a reasonable time period. Ultimately, fleet operators may be more willing than personal-use consumers to consider multi-year paybacks, but they will still want to see returns relatively quickly. At the same time, high mileage fleets may feel that charging operations impede fleet mission.

#### Market Perception

Perhaps the most critical challenge affecting fleet adoption of electric drive technology will be fleet adopters’ impressions about the technology and its ability to meet their operational needs. Even when a compelling economic case exists, fleet operators will need to be confident that the vehicles can accomplish the mission.
Technology Costs

Electric drive technology—HEV, PHEV, and EV—will likely carry a significant upfront cost premium over internal combustion engine vehicles across all vehicle sizes. While fleet operators may be willing to evaluate the costs and savings of operating electric drive vehicles over the entire life of the asset, it is nonetheless important to understand the key drivers of technology costs. If targeted to the right fleet applications, the cost premium for electric drive vehicles can be quickly recovered through operational savings. Alternative business models may also play a role. In general, batteries are the key cost driver for electric drive technologies, though powertrain components and infrastructure are important as well.

Batteries

Battery costs vary by chemistry and by the type of drive train for which they are optimized. Lithium-ion batteries, optimized for light-duty HEV applications currently carry an average cost of $1,500 per kWh. The cost is slightly higher for HEV batteries optimized for heavier applications. These batteries are designed to provide significant power support to the internal combustion engine during certain driving functions like acceleration. Because HEV batteries tend to be smaller relative to the energy required for PHEV applications, they carry a lower cost in absolute terms.

Lithium-ion batteries for PHEVs and EVs currently average $800 per kWh. These batteries must be optimized to carry a large amount of energy to power autonomous driving during charge-depleting mode. The amount of energy required for PHEV applications is somewhat less than for EVs, so these batteries must also balance power and energy. The result is that PHEV batteries can be more expensive than EV batteries on a per kWh basis. Both EV and PHEV batteries represent large shares of total vehicle cost. For example, a 16 kWh PHEV battery can equate to 29 percent of final vehicle cost, while a 24 kWh EV battery can equate to as much as 33 percent of final vehicle cost. In heavier applications, this share can increase as the cost of battery management components also increases.

Battery Life

Battery life can be measured in terms of calendar life, but cycle life is the most commonly cited metric. Cycling refers to the process of discharging and recharging batteries. The cycling of lithium-ion batteries is most detrimental to their health when they are deeply discharged; that is, when their energy is so completely depleted the remaining state of charge of the battery is very low. Alternatively, battery health is also severely damaged when the battery is held at a very high state of charge for long periods of time. At a practical level, the deleterious effects of deep cycling and overcharging result in a rapid reduction of usable battery capacity. In an electric vehicle, this would effectively shorten the range of the car and ultimately cut short the calendar life of the battery. The first generation of large-format lithium-ion batteries is targeting a cycle life of 1,500 to 3,000 cycles. At the most basic level, a battery with a 3,000 cycle life would last the average driver about eight years if it were fully cycled once each day. A more tangible metric for many drivers may be the mileage life of their battery. Battery mileage life will vary depending on the calendar history of the battery, the way the vehicle is driven, and the drivetrain configuration. HEV batteries, for example, will have mileage lives as high as 250,000 miles or more, because they are cycled extremely narrowly. Alternatively, EV batteries are targeting 150,000 miles over the life of the battery.

Nameplate or Usable Energy?

When describing the cost and performance metrics of today’s large-format automotive batteries, it is important to distinguish between ‘nameplate’ and ‘usable energy.’ Nameplate figures assign a value—for example, cost or capacity—to the entire battery pack and divide that figure by the maximum number of kilowatt hours of battery power. The nameplate cost of a battery reflects the total cost of the battery divided by the total number of kilowatt hours (kWh) of capacity. Therefore, a pack that costs $12,000 and has 24 kWh of capacity would have nameplate battery costs of $500 per kWh.

However, in practice the nameplate energy capacity of today’s batteries is not typically fully utilized. Most battery suppliers are building in a reserve margin at the low- and high-end of the battery’s state of charge to avoid overheating and excessive discharge. In some cases, this reserve portion can represent up to 50 percent of a battery’s nameplate capacity. In other words, a 24 kWh battery with a 50 percent state of charge reserve margin only has 12 kWh of usable energy. In this case, the $12,000 battery would have usable energy costs of $1,000 per kWh.

In general, nameplate capacity is the more commonly used metric by industry. Therefore, whenever battery costs are quoted in this report, figures reference nameplate capacity.
Another issue related to cost and performance is battery utilization. In particular, some current PHEV batteries utilize a 50 percent state-of-charge window. That is, a PHEV-40 battery today is designed to require only 8 kWh of its 16 kWh capacity in order to travel 40 miles in charge-depleting mode. This practice comes at significant cost, driving current battery prices higher than technical requirements. In first-generation applications, PHEV manufacturers made the strategic decision to add extra capacity in order to ensure end-of-life performance metrics and meet battery warranty requirements. However, advancements already achieved have reduced the need to over-specify PHEV batteries and expanded the state-of-charge window, thereby reducing costs for the next generation of assembled battery packs.

**Industry Dynamics**

While battery costs are still high, general industry trends suggest important progress is being made. Over the last several years, there have been significant reductions in large-format lithium-ion battery prices. As recently as 2008, EV battery prices were often quoted at $800 - $1,000 per kWh. During this early market phase, installed costs were often quoted at $600-$750 per kWh. The next five years are likely to be characterized by a highly competitive market stemming from the entrance of multiple battery OEMs with excess capacity. Competition for limited unit demand will result in lower battery prices. After 2015, there may be a consolidation of battery suppliers. At the same time, unit demand will ramp up to sustainable levels, generating cost and price benefits from volume-related cost reductions as well as from standardized manufacturing practices and optimized supply chains.

**Component Cost**

The advanced components required in electric drive-trains also contribute to higher vehicle costs. Onboard chargers, power inverters, and electric motors all represent significant portions of an electric vehicle’s upfront costs. While relatively small with respect to battery costs, electric drive system components carry higher costs than their ICE counterparts, accounting for approximately one third of the total EV drivetrain cost. For GEVs to reach cost parity with ICE vehicles, the cost of electric drive components will need to be reduced through innovation and volume production.

The lack of a mature, high-volume market for electric drivetrain components is a significant cost driver. The manufacturing processes and design technologies for these components are largely tailored to low-volume industrial applications, which results in processes and technologies optimized around lower engineering and manufacturing investment rather than lower variable cost. As these components are commercialized in higher volume automotive applications, there will be significant advances in the state of the art for component packaging and assembly.

Such advancements can be seen by comparing the 2004 Prius and 2007 Camry hybrid traction drive system. The inverter in the 2007 Camry is approximately 30 percent smaller and 15 percent lighter while supplying a motor with a 40 percent higher power rating.4 As production scale increases across the industry, design and manufacturing improvements will continue to drive comparable improvements.

Equally important to component cost and performance improvements will be an automotive-capable supply base. In many cases, the supply chains around electric drivetrain components are immature for the needs of GEVs. The state of the current supply chain has been identified by some vehicle OEMs as a constraint to GEV market growth.5 For example, integration of motors and gear boxes will likely be a source of cost and size reductions. However, doing so will ultimately require a realignment of the supply chain. Today, capability to design and manufacture integrated assemblies does not exist within many of the traditional gear box and high power motor suppliers. Partnerships to address this need are beginning to emerge, such as the strategic relationship between Borg Warner and UQM to develop integrated traction drive solutions.6 As the market continues to develop, further strategic and equity partnerships are likely to emerge.

**Charging Infrastructure**

In general, charging infrastructure costs vary by the type of technology and location in which they are installed. For the majority of fleet applications, Level I charging (120v) will be insufficient for PHEV and RY charging. The exception would be low mileage, low utilization fleet vehicles that tend to sit idle for longer periods, perhaps certain executive and federal government fleet vehicles. But these are not driving characteristics that will typically support adoption of grid-enabled vehicles—at least from a purely economic perspective.

More commonly, fleets that have access to central parking facilities and that have at least one somewhat lengthy opportunity to charge per day (overnight, for example) will opt for Level II charging (220v). Level II...
changers—often referred to as electric vehicle supply equipment—currently available in the market can be purchased for approximately $2,000 per unit (hardware only), though the cost varies widely depending on the OEM and the charger’s software capacities. Software and installation costs can add as much as several thousand dollars to the cost of a Level II charger for use in a fleet depot. Units installed in public will carry higher installation costs. In the most common configurations, each unit is capable of charging one to two vehicles at a time. Figure 2E contains the associated charge times for a number of battery sizes in multiple configurations.

Scaling infrastructure cost estimates based on the number of PHEVs or EVs owned provides useful context toward evaluating the impact of charger cost on the total cost of ownership for GEVs in fleet applications. Assuming a one-time installation cost for Level II chargers of $2,000, and that local electricity grid hardware and software upgrades represent an additional $10,000 to $15,000 borne by the fleet operator, the cost to establish a central charging network for 10 EVs would be more than $30,000. This is a significant capital outlay that may impact the broader decision-making process for fleet operators seeking to adopt grid-enabled vehicles.

**Fast Charging**
Level III charging, or DC to DC fast charging, can reduce charge times for grid-enabled vehicles to a very manageable 20 to 30 minutes for a fully depleted passenger vehicle battery. The earliest Level III chargers to enter the market have been designed with 50 kW of power and, allowing them to provide 24 kWh of power in slightly less than 30 minutes. DC to DC fast charging into their business or technology plans. Individual fleet operators may also find it difficult and costly to train or hire in-house staff to maintain and service electric vehicles, although the maintenance requirements of electric drive vehicles are substantially less than those of ICE vehicles.

Vehicle leasing removes the capital burden of the outright ownership model, allowing fleet operators to treat vehicle acquisition as an operational expense. Lessors that include maintenance and other services in the lease price can help reduce labor costs for large fleet operators, and lessors may also be able to secure significant volume purchasing discounts from vehicle OEMs, lowering costs for their lessees.

**Costs for Level III chargers have fallen by approximately 25 percent over the past 12 months, but at roughly $37,500 per unit, they are still significantly more expensive than Level II chargers.**
In addition, the cost of Level III charging on automotive batteries is still being evaluated by battery makers. The amount of heat generated by fast charging could have deleterious effects on battery life. However, as of Q4 2010, there is very little available data on the effect of DC to DC fast charging on battery life. The benefit of the technology seems apparent from the driver’s perspective, but its impact on the battery and the grid is still largely untested. In fact, a number of major battery makers and vehicle OEMs do not factor fast charging into their business or technology plans.

**The costs and benefits of the different ownership models could ultimately have an impact on the likelihood of a fleet operator to adopt electric drive technologies.** For example, the high capital cost requirements of today’s HEVs, PHEVs, and EVs, particularly in applications heavier than a passenger automobile, might not be suitable for outright ownership. Even extremely large businesses may be unwilling to expand capital budgets to support substantial volumes of PHEV or EV purchasing. Individual fleet operators may also find it difficult and costly to train or hire in-house staff to maintain and service electric vehicles, although the maintenance requirements of electric drive vehicles are substantially less than those of ICE vehicles.

**Given higher upfront (capital) costs and lower ongoing operating expenses associated with fleet electrification, a shift towards financing/leasing (methods of spreading the high capital expenditures over the life of the asset) will likely become more important for fleet operators seeking to leverage this technology.**

---

**FIGURE 2E
EV Battery Charge Times**

<table>
<thead>
<tr>
<th>VEHICLE</th>
<th>BATTERY CAPACITY</th>
<th>CHARGING METHOD</th>
<th>CHARGING POWER</th>
<th>FULL CHARGE TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Level 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger Car</td>
<td>24 kWh</td>
<td>17 kW</td>
<td>9.8 hrs</td>
<td></td>
</tr>
<tr>
<td>Class 5 Truck</td>
<td>65 kWh</td>
<td>6.5 kW</td>
<td>9.8 hrs</td>
<td></td>
</tr>
<tr>
<td>Class 7 Truck</td>
<td>80 kWh</td>
<td>12 kW</td>
<td>6.7 hrs</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 2F
Sample Cashflow Impact of Vehicle Leasing vs. Ownership (CapEx vs. OpEx)**

Fleet operators must constantly balance the need for access to capital with the need for new vehicles. In large companies, fleet managers must also compete with other corporate divisions for scarce capital that must be directed toward its most productive uses. The form of vehicle ownership a company or institution chooses plays a significant role in balancing these demands. Approximately 80 percent of fleet automobiles and class 1-5 trucks in operation—8.7 million cars and trucks—were owned outright by their operators as of January 1, 2010. In this ownership model, the capital costs of electric drive vehicles will present a substantial challenge in most companies and institutions. The remainder of cars and class 1-5 trucks in operation were leased.

Both ownership and leasing have advantages and disadvantages. Company/institutional ownership can allow a fleet operator the flexibility to acquire vehicles specialized for its needs, particularly in the case that the fleet operator is large enough to make high volume acquisitions. Some fleet operators also prefer to maintain vehicles in house with internal maintenance staff. On the other hand, outright ownership can tie up a significant amount of capital for a fleet owner. For example, a class 5 utility service EV might cost as much as an additional $25,000 to $30,000 in 2015. Capital that is put toward asset acquisition in this model is unavailable for other productive uses.

**FIGURE 2G**

- **Battery Replacement**
- **Lease**
- **Own**

<table>
<thead>
<tr>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20,000</td>
<td>40,000</td>
<td>40,000</td>
<td>40,000</td>
<td>40,000</td>
<td>40,000</td>
</tr>
</tbody>
</table>

Source: PRTM Analysis
Battery Residual Value

Resale value often plays an important part in the overall financial value of a vehicle. Depending on who owns the vehicle and the type of ownership transaction, resale value can have a significant impact on financial risk as well. In both the commercial and passenger markets, entities that purchase and own a vehicle assume the full risk associated with resale value. If the vehicle is kept in good condition, a high resale value can offset the total cost of ownership significantly. If market resale value is low, or the vehicle is in poor condition, an owner might choose to hold onto the asset for a longer period of time, up to the full useful life of the technology.

In the personal-use market, a consumer who opts for a closed-ended lease will typically assume less risk associated with resale value—the risk sits largely with the lessor. The assumed resale value of a vehicle—determined by market trends and changes in demand for different vehicle sizes and types—can have significant impact on the total estimated value of the vehicle and therefore on monthly lease payment amounts. In a sense, lessors try to transfer some of the resale risk back to the consumer.

From a business model perspective, commercial leasing benefits significantly from the widespread use of open-ended leasing, or TRAC leasing. TRAC leasing has a resale risk profile that is most similar to ownership for different vehicle sizes and types—and can have significant impact on the total estimated value of the vehicle and therefore on monthly lease payment amounts. In a sense, lessors try to transfer some of the resale risk back to the consumer.

As a result, commercial leasing entities should be much more willing to consider leasing electric drive vehicles, including PHEVs and EVs. However, because there is little experience with the resale value of grid-enabled vehicles, there may initially be a high degree of risk associated with resale value regardless of ownership model. Commercial entities that choose outright ownership—applicable to the vast majority of fleet vehicles in the United States—could be hesitant to purchase vehicles that have very high upfront costs and no proven resale market value. While the risk threshold is much lower for commercial fleet lessors due to reduced capital requirements, these customers may still be hesitant to be responsible for an unknown resale value. The issue may be less of a challenge in fleets that hold onto vehicles for longer periods of time and do not typically expect high resale value.

The primary driver of uncertainty regarding the resale value of grid-enabled vehicles is the battery. A lack of practical experience in the long-term cycle performance of large-format batteries makes it difficult to make assumptions about the ability of EVs and PHEVs to continue to perform at desired levels past a certain point. This uncertainty could be exacerbated by a lack of transparency surrounding battery health, but most OEMs are including advanced software and other telematics that will allow for an accurate read-out of battery health when PHEVs and EVs are ready for resale.

Ultimately, the resale value for these vehicles can only be determined through market experience. The traditional hybrid vehicle market does offer some case for optimism, however. Particularly during periods of high fuel prices, HEVs have performed extremely well at auction. During mid-2008, as retail fuel prices passed $4.00 per gallon, Toyota and Honda hybrid models saw increases in month-over-month resale value that exceeded the increase in comparable fuel efficient ICE models. (See Figure 2H).

Obviously, the unique market conditions that existed in 2007 and 2008 should not necessarily be interpreted too broadly. By the end of 2009 and into late 2010, hybrid models performed worse than their peers at auction, as fuel prices have returned to much more manageable levels. One conclusion from this is that macroeconomic conditions can drive demand for specific vehicle technologies, and vary over time. However, the data also suggests that there is nothing inherently unattractive about electric drive vehicles in secondary markets. In fact, in the right market conditions, and when performance has been demonstrated, electric drive vehicles outperform comparable ICE models.

Secondary Battery Market

The resale value of PHEVs and EVs could be significantly enhanced by considering the residual value of the battery itself after it has degraded beyond its usefulness for automotive applications. Possible second life applications include: backup power for homes, offices, and cell-phone towers; storage for intermittent renewable electricity supplies; secondary vehicle markets; or separated components. The residual value of the battery will be determined by the net residual capacity (the sum of each remaining cycle’s capacity) multiplied by the value of that capacity. Residual value will likely exceed standard financial depreciated value but fall below the cost of comparable new battery (See Figure 2G).

Today, estimating the residual value of used large-format automotive batteries is an educated guess at best. In large part, this is simply an issue of experience. Sufficient empirical data cannot and will not be collected until the first several hundred or several thousand PHEV and EV batteries reach the end of their useful life in a real world automotive application. Early test data suggests that lithium-ion batteries may still possess 70 to 80 percent of their potential cycle life at the point where they are no longer fit for automotive use. But this needs to be borne out by practical experience.

One report produced by researchers at Sandia National Laboratories identified as many as eight possible options, including: transmission support; area regulation and spinning reserve; load leveling/energy arbitrage/transmission deferral; renewables firming, power reliability and peak shaving; light commercial load following; distributed node telecommunications backup power; and residential load-following.


27 PHEM analysis.


24 As
analysis found that four of these applications may be economically and technically feasible today.28

One secondary application is currently being demon-
strated at the University of Delaware’s Mid-Atlantic
Grid Interactive Car Consortium (MAGICC). At the
university, a plug-in electric vehicle has been responding
in real-time to the PJM regu-
lation signal since October
2007 (PJM Interconnection is a regional transmission orga-
nization). It has provided both
regulation services and impor-
tant data about vehicle-to-grid
applications. As a follow up,
PJM and the University of
Delaware will be aggregating
three 18 kWh vehicles with a 1
MW stationary battery trailer
to participate in the PJM market for regulation, earning
each vehicle between $7 and $10 for the 18-20 hours they
are plugged in and contributing to the regulation stor-
age needs of the grid. This demonstration also has direct
application to second-life use as stationary sources of
ancillary services to the grid.

It is important to note that used batteries will face
extraordinary competition in many potential second
life applications. For example, early attention for secondary
battery applications has tended to focus on the electric
power sector, either for residential back-up storage or
for firming up intermittent renewables. Yet, today, most
grid stabilization is achieved through spinning reserves
of natural gas, a relatively inexpensive fuel that is quite
familiar to most grid operators. In residential applica-
tions, back-up power is most commonly achieved using
natural gas, diesel, or propane generators.

Finally, a lack of transparency could significantly
impact the market’s ability to price used lithium-ion
batteries. Individual consumers will use their vehicles
differently. The frequency at which batteries are
charged, the depth to which they are discharged, and
the number of quick charge occurrences will all impact
their ability to perform after they are removed from a
vehicle. To address this issue, a number of battery sup-
pliers and automakers are incorporating diagnostic and
telematic systems in vehicle batteries. Ultimately, the
possibility exists to assign each battery a performance
rating so that markets can appropriately value its
remaining capacity.

Despite the challenges, most experts and industry
participants agree that used batteries will have some
value beyond scrapping. General Motors recently esti-

te that the typical 16 kWh Chevy Volt battery pack
will have “50 to 70 percent of its life left” after the expi-

ration of GM’s 8-year, 100,000 mile lithium-ion battery
pack warranty.29 GM has also formed a partnership with
ABB Group, the world’s largest provider of electrical
power grid systems, to explore the options for used large-
format automotive batteries.30

In September 2010, Nissan Motor Corp. and
Sumitomo Corp. of Japan announced the establishment of
a joint venture to commercialize used automotive
lithium-ion batteries.29 Nissan has characterized the

vehicle, called the 4R Energy Corp., as an opportunity to
help reduce the upfront cost of lithium-ion battery packs
that power the all-electric Leaf.

Fleet Infrastructure Issues

While fleets that have access to central parking facilities
may find that single-point installation leads to efficien-
cies, infrastructure will still represent a substantial
component of total cost in many cases. Charger costs

will depend on the driving characteristics of a given fleet.
Predictability of routes, miles driven (or hours of opera-
tion for some fleets), and charge times will affect the type,
number, mix, and location of chargers—and therefore the
cost burden of charging infrastructure.

For example, a fleet that drives consistently between
70 and 100 miles daily, operates no more than 12 hours per
vehicle per day, and parks most of its vehicles in a central
depot would be able to charge its fleet with Level II charg-
gers at a ratio of about one vehicle per charger. This is based
on the assumption that a battery charge for an EV will
provide 100 miles of charge-depleting range per day and
therefore would not require more than one Level II charge-
day at roughly four to six hours. This vehicle would fall
into quadrant 1 of Figure 2I. Fleet vehicles that spend the
night parked at the driver’s home, such as many sales fleets
or local law enforcement vehicles, would require a home
Level II charger plus some charging capacity in the depot.

Fleets with vehicles that drive distances in excess
of EV battery capacity or fleets that drive unpredictable
distances will require some additional chargers in the field
along highly transited roadways or at particular client or
supplier locations. This would be true in general for most
PHEVs as well, as the key cost metric to be maximized
will be miles driven on electricity. These fleets may pos-
sibly also require some fast charging capabilities and fall
into quadrants 2 and 3 of Figure 2I. Fleets in quadrant
4 that drive more miles and have less predictable routes
will incur higher infrastructure costs in the form of more
chargers in the field and would likely be in need of signifi-
cant Level III capacity for EV adoption. In practice, such
fleets might choose HEV or PHEV technology instead.

An additional factor to consider is the amount of
time spent parked in a charging location. For instance, a
fleet with short driving distance and predictable routes
as the example for quadrant 1 above, may actually require
a quadrant 4 charging infrastructure if it runs more than
one shift on a vehicle per day. There may not be enough
time spent parked to achieve sufficient charge with a
Level II charger.

Finally, commercial and government fleet facili-
ties may require both external and internal electrical
upgrades to support charging infrastructure. External
utility service transformers are typically sized based on
the type of building and the square footage. Upgrading
these transformers—and the service wires and main
dconnect line size—to support special needs such as GKEV
charging will result in increased costs for fleet operators.
Such upgrades can also require more expensive conduc-
tors, electrical panel boards, and service wires.

Upizing the internal transformers within a large
commercial or government building, such as those that
might serve charging stations, may require upizing con-
ducts (which are often encased in concrete or difficult to
access), increasing conductor sizes, and installing larger
panel boards. It is important to note that these upgrades
are easier to accomplish during initial building design as
opposed to retrofit.

FIGURE 2I

Directional Indicator of Charging Infrastructure Costs

-- End --
Utility Impact of Dense Charge Networks

The power draw of plugging in a PHEV or EV at any given point in time can be the equivalent of adding at least one new house to the grid. In certain fleet applications, larger battery and onboard charger specifications may significantly increase this load. Moreover, in fleet applications that utilize centralized refueling configurations, the impact on the local distribution system is likely to be particularly acute. The fact that most drivers, including fleet operators, operate their vehicles almost exclusively during the day minimizes the effects on the power generation and delivery system, because the vehicles will be charged off-peak, when there is surplus power available on the grid. However, bringing a fleet of EVs in a small charging space will bring an unusually high burden to the grid. However, bringing a fleet of EVs in a small charging space will bring an unusually high burden to on the grid. However, bringing a fleet of EVs in a small charging space will bring an unusually high burden to on the grid. However, bringing a fleet of EVs in a small charging space will bring an unusually high burden to.

Generation

Since electricity cannot be stored, the electricity grid is constructed to meet demand during periods of highest load - typically hot summer days. In fact, to meet reliability requirements, regulators have driven utilities to overbuild their systems with a 12-20 percent reserve margin beyond forecasted peak capacity. In addition, utility power requirements generally follow a pattern of high demand during the mid-day hours and very low demand in the evening. Thus, the system usually operates with significant spare generating capacity—particularly at night— that can be utilized for charging plug-in electric vehicles. This feature of the power sector, which represents a low-cost way to deliver fuel to electric vehicles, has generated significant optimism among electrification advocates. In 2007, the Pacific Northwest National Laboratory (PNNL) released a study demonstrating more than 160 million PHEVs could be powered in the United States without building a single new power plant. This scenario is unlikely to occur on its own, however. Most such analyses assume that a very high portion of vehicle charging occurs off-peak. In fact, the PNNL study assumes perfect off-peak charging. For fleet operators that park vehicles overnight at home or a central depot, off-peak charging may be somewhat straightforward, though demand for charging in the early evening right after business hours could potentially be higher. This is especially likely to be true if the cost of charging an EV or PHEV is the same at 6:00pm and 6:00am. Time-of-use pricing mechanisms could allow utilities to employ price signals to change behavior.

Analyzing GEV Impact On Power Generation

In 2008, Oak Ridge National Laboratory released a comprehensive simulation analysis of PHEV charging and its impact on power generation. The analysis was segmented by North American Electricity Reliability Council (NERC) regions. The analysis assumed that 19.6 million PHEVs would be on the road in the U.S. by 2020, and modeled the effect of multiple charging scenarios in different NERC regions. Charging was varied by strength of charge and also time: early evening or night charging.

Figure 2K presents the results of peak day charging by PHEVs in the East Central Area Reliability Coordination Agreement (ECAR) region. In this case, unconstrained early evening charging by PHEVs using a 6 kW charger surpassed the typical peak load. The implication is that in this instance, the utility would, in fact, need to add new generation capacity to support PHEV charging. And while this analysis probably represents a kind of worst case scenario—6 kW vehicle chargers are not the norm for light-duty vehicles today—it highlights the need for careful planning in managing the interface between utilities and plug in electric vehicles. Ultimately, utilities will need levers, including price signals and smart grid technology, to carefully deal with EV and PHEV customers in both fleet and personal-use applications.

FIGURE 2K
Peak Day PHEV Charging in ECAR, 2020

Source: Oak Ridge National Laboratory

6 kW Evening
2 kW Evening
1.4 kW Evening
6 kW Night
2 kW Night
1.4 kW Night
Base

Source: Oak Ridge National Laboratory


There is already precedent for this approach emerging in the consumer space. In a pilot program accessible to all consumers, Detroit Edison (DTE Energy) recently announced a time-of-use GEV rate plan that sets off-peak electricity rates at 7.6 cents per kWh. DTE defines off-peak as between 11:00pm and 9:00am Monday through Friday, and anytime on weekends. The on-peak rate for RV and PHV charging is set at 18.2 cents per kWh. By comparison, the standard residential rate in DTE’s service territory is 12.3 cents per kWh. (The rate plan was approved by the Michigan Public Services Commission in August 2010.) Ultimately, off-peak rates may be both economically advantageous and convenient to access for fleets that park overnight.

Pacific Gas and Electric has also introduced a tiered rate plan for GEVs. The “Experimental Time-of-Use Low Emission Vehicle rate” is mandatory for drivers of grid-enabled vehicles who are on a residential electricity rate and plan to charge at home. PG&E’s rate plan is also designed to deal with issues unique to its service territory. During the summer, when air conditioning loads can occupy a significant share of neighborhood transformer capacity, peak vehicle charging rates are 28 cents per kWh. Off-peak rates for vehicle charging are as low as 5.0 cents per kWh.

**Distribution**

In the near term, particularly when considering fleet applications, power generation issues are not likely to be an urgent problem. More significant power generation challenges could be associated with deployment of millions of EVs and PHEVs, but this will take time. Of course, it will be critical to have necessary smart grid and other load management technologies in place to avoid the most damaging aspects of unmitigated charging by a large number of grid-enabled vehicles.

However, preparing the local distribution infrastructure for fleet plug-in electric vehicle charging may present a much more immediate and pressing challenge. While GEVs are plugged in and charging, they represent a significant power draw. A Level II charger operating at 220 volts on a 15 amp circuit is expected to draw 3.3 kilowatts of power. A load that is similar to the average load in a typical U.S. home. In larger vehicle applications, the power draw can increase substantially. Medium-duty plug-in electric trucks may require chargers in excess of 12 kW. For heavy-duty GEVs, the charger could easily exceed 10 kW. In order to support the reliability of the electrical grid, utilities will have to take steps to ensure that they can deliver power over the last few feet of power lines from the transformer to a fleet depot or other charging facility (including residential garages in the case of fleet vehicles that return to a fleet depot or other charging facility (including residential garages in the case of fleet vehicles that return home each night with employees in sales or local government entities). In the case of several fleet vehicles parked at a central depot, the issue will be most acute.

One recent analysis from the Electric Power Research Institute (EPRI) examined the impact of PHEV charging on neighborhood transformers of varying capacity. The EPRI analysis concluded that plugging in just three PHEVs to charge at 240 volts overloaded 114 of 314 transformers examined during peak hours and 68 of 314 transformers during off-peak hours. Smaller transformers showed the highest level of vulnerability. The analysis reported that plugging in a single PHEV to charge at 240V would have caused 68 percent of the 25kVA transformers examined to exceed their emergency rating. Pure electric vehicles, with their bigger batteries, may present an even more significant issue, and clustered charging—such as that likely to be associated with fleet depots—will require careful planning.

Most utility managers are confident that these issues can easily be addressed. Commercial and industrial entities may be better equipped to communicate with utilities than typical residential customers. Moreover, the likely impact of transformer overloads in many cases is simply an increased depreciation of the useful life of the transformer. Nonetheless, system-wide costs can be minimized over time if the strain placed on transformers is reduced. Once again, technology that enables managed (staggered) charging of vehicles during off-peak hours can help moderate the impact on the grid and maximize system efficiency.

**Preparing City Governments**

As PHEVs and EVs are integrated into fleet and utility infrastructure, local building codes and regulatory statutes will be an added obstacle in many cases. Operators that choose to adopt PHEVs, EVs, and their requisite charging infrastructure will find themselves navigating a myriad of processes to acquire the necessary permits for successful installation. It would be typical to expect the process of installing a charging station to begin with the request for a permit from the local city government. Local research, which could include inspection of a home or depot’s electric connection and wiring, might also be required. Once installed, inspection by a local regulator could be required before use of the charger.

In the current environment, fleet operators will find that the process of ensuring regulatory compliance differs significantly in various operating locations. In fact, large fleets that operate in multiple regions throughout the nation can expect contradictory regulations across regions. Developing a comprehensive set of streamlined best practices for infrastructure permitting and inspection will help to make this process more uniform for both the end user and resource-constrained local governments. These guidelines could be extended to include public charging infrastructure, however, the guidelines would need to be more of a general nature as these installations may be much less uniform.

Ultimately, fleet operators that want to deploy EVs and PHEVs will need to work collaboratively with their local utilities as well as state and local government offices in order to ensure regulatory compliance. In many cases, this could be relatively straightforward as larger commercial and industrial enterprises may have a high level of communication with utility and government officials.

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37 Issues with neighborhood level transformers are likely to be less pronounced in areas with large air conditioning loads, especially if vehicles are charged at night when air conditioning loads typically lighten relative to late afternoon loads.
Market Perception

Despite the potential economic benefits of electric drive technologies, the most important factor determining their uptake in fleet applications may be the way the vehicles are perceived by fleet managers. While total cost of ownership is consistently ranked as the most important factor during vehicle acquisition—a notion that should benefit electric drive vehicles—other factors clearly play an important role. Moreover, an analysis of total cost of ownership requires certain assumptions that will vary by operator, including assessments of future fuel and battery costs, technological advancement, and macroeconomic conditions. Both of these factors can dramatically impact the total cost of ownership, and yet each is somewhat uncertain, requiring fleet managers to make informed guesses that are ultimately subjective.

Assessing Operational Cost Savings

Fuel price volatility continues to rank among the most significant factors hindering adoption of the full range of alternatives to petroleum. Sales of gasoline hybrid electric vehicles in the consumer market provide a case in point. The strongest period of growth in year-over-year hybrid sales occurred between 2004 and 2007, a period during which the average price of unleaded regular gasoline in the United States increased by nearly 50 percent, from $1.88 to $2.80/gallon.44 Even in 2009, as oil prices fell, hybrid sales proved somewhat resilient, falling by just 7 percent compared to 22 percent for the broader auto market.45

But a different story has emerged in 2010. With gasoline prices now steady at $2.70 per gallon, hybrid sales have continued to fall, while broader auto sales have rebounded. Through the first three quarters of the year, aggregate hybrid sales are down by 10 percent compared to 2009, while broader auto sales have rebounded and are set to increase by nearly 10 percent.46 More importantly, the personal-use auto sales mix is increasingly shifting back to heavier classes: sales of midsize and large SUVs are up 33.3 and 13.7 percent in 2010 compared to the first three quarters of 2009.47 The market has adjusted to gasoline prices above $2.50 per gallon and is seemingly unconvinced that the high prices of 2008 will return.

While commercial fleet operators continue to downsize vehicles where possible, most fleet managers do not explicitly engage in fuel price hedging, and they do not view electric drive vehicles as a way to offset the higher—and potentially volatile—costs of petroleum fuel. Assessments about future petroleum prices are simply too complex and lacking in transparency. Maintenance Costs

It is also not entirely clear that fleet managers will be willing to factor maintenance savings associated with electric drive vehicles into their acquisition strategies. Vehicle OEMs report that while these savings are real and significant, fleet managers will be unlikely to factor them into their decision process.48 There may be several reasons for this.

First, some fleet vehicles are relinquished ahead of critical maintenance milepostes. For example, the average mileage of compact cars entering auction after fleet use ranges from 40,000 to 65,000 miles between 2000 and 2005.49 At the same time, the maintenance costs as a share of operating costs for these vehicles tend to sharply increase after 50,000 miles. In other words, just as maintenance costs begin to rise, fleet managers typically remark the vehicles. Of course, a portion of the postponed maintenance needs may be factored in to the resale value of the vehicle as a lower price, but the urgency of upcoming repairs may be difficult for market participants to accurately assess. Nonetheless, a fleet operator in this instance might be less attracted to the relatively lower maintenance costs of electric drive vehicles, at least until the resale value of EVs and PHEVs is much clearer than it is currently the case.

Second, fleet managers who service their vehicles via internal maintenance staff may be concerned that additional training of existing workers—or hiring of new, specialized workers—will be required to support electric drive vehicles. The transaction costs associated with such an upgrade may present fleet managers with an additional and unwanted burden.

Expected Value

A final point on cost perception is the rate at which fleet managers expect to recoup an EV investment within approximately four years.46 As the survey notes, “any payback time that is longer than 4 years may require a lower discount rate than many fleet managers would be willing to use.”

Corporate environmental and social responsibility initiatives may expand this period, but the number of vehicles that will be purchased based on such metrics alone seems likely to be low. Fleet operators must ultimately be presented with a compelling economic proposition in order to seriously consider investing in an alternative technology.

Shifting Institutional Norms

Incorporating EVs and PHEVs into a fleet can raise important hurdles in terms of organizational processes for both public and private sector institutions. EVs and PHEVs will require changes to acquisitions as well as operational processes that are engrained in most institutions. In many cases, uptake of these technologies will be hindered by unwillingness to increase flexibility and adjust common current practices.

In terms of acquisitions strategy, a number of fleet operators report that their institution’s capital budget for acquiring vehicles is managed separately from the operational budget.47 Moreover, in some cases, these budgets are actually managed by different corporate business units.48 This presents an obvious difficulty: electric drive technology will significantly stress the acquisition manager’s budget while he reaps none of the benefits of lower operating costs over time. In cases where vehicles are leased, this issue may be less of an obstacle. But the 80 percent of fleet vehicles that are purchased and owned in the traditional model, organizational change will be needed.
PART THREE
Identifying Fleet Opportunities

3.1 OVERVIEW
3.2 MODELING ASSUMPTIONS
3.3 KEY FINDINGS
3.4 CASE STUDIES
3.5 FLEET ADOPTION OF GEVS IN 2015

FLEET ELECTRIFICATION Florida Power and Light Company's hybrid bucket truck and electric plug-in car are shown at the groundbreaking ceremony for FPL's Martin Next Generation Solar Energy Center in Indiantown, Florida.
ABSTRACT

Part One of this Roadmap outlined how and why commercial and government fleet owners could represent an important early market segment for grid-enabled vehicles. Part Two discussed several challenges that may need to be addressed through policy support and adjustments to the operational norms of fleet operators. Part Three presents the results of total cost modeling conducted for fleets in various industries and sectors of the U.S. economy. The analysis was performed for HEVs, PHEV-40s, and EV-100s.

The analysis finds that grid-enabled vehicles can provide significant economic benefits to fleet operators. These benefits will be maximized if GEVs are targeted to fleet applications whose operational attributes facilitate the most efficient allocation of battery capacity and charging infrastructure. Optimizing investment in upfront costs allows fleet operators to benefit from the reduced operating costs of plug-in hybrid electric vehicles and electric vehicles in the near-term without sacrificing mission in most cases. Targeted policy support has an additional positive impact.

CHAPTER 3.1

Overview

The Fleet Electrification Roadmap utilizes total lifecycle cost modeling to compare the economic competitiveness of various drivetrain configurations across fleet segments. Comparisons were facilitated through the use of segment clusters across fleet segments. The analysis was performed for HEVs, PHEV-40s, and EV-100s.

In order to better understand the business, economic, and cost-saving opportunities presented by electrification of vehicle fleets, an economic model was developed for the Fleet Electrification Roadmap. The model compares the total cost of ownership of sample vehicles by class and industry for a given acquisition year. Technologies considered were ICE, HEV, PHEV-40, and EV-100. The purpose of constructing the model was to identify those fleet segments that will realize positive economic returns through use of electric drive vehicles in the near term, making them likely adopters of electric drive technology. Combined with an assessment of the relative ease or difficulty of switching to EVs and PHEVs for a given industry, total cost modeling was also used to create scenarios for future vehicle technology penetration rates.

To conduct the modeling analysis, vehicle segments with similar physical and operational attributes across the various industries were first identified. Establishing these segment clusters helped to create a manageable data set of vehicles grouped together according to a standardized set of shared attributes. The key physical attribute used in this analysis was DOT vehicle size/weight classification. The primary operational attributes used included:

- fuel efficiency;
- average miles traveled per day;
- average utilization rate;
- average number of stops per day;
- average length of stops/idles;
- level of route predictability; and
- refueling behavior.

FIGURE 3A

VIO by Industry (2009)

FIGURE 3B

VIO by Class (2009)
Chapter 3.2 Modeling Assumptions

In order to isolate the effects of fleet optimization and public policy, multiple scenarios were analyzed. Standard assumptions regarding the pace of technological change in the automotive industry as well as mainstream assessments of energy prices were also incorporated.

The model used for this analysis is a total cost of ownership model. As discussed in Part One of this Roadmap, total cost of ownership is a quantifiable and objective measure that constitutes one of the principal purchasing criteria for fleet operators. Fleet operators track and maintain historic operating cost data, which provides a rich data set for use in comparing operational and other norms. In general, fleet operators are better equipped to consider the total economic implications of transitioning to electric drive vehicles than individual consumers.

One of the challenges of comparing internal combustion engine vehicles to their electric alternatives is that there is a fundamental shift in costs from operating expenses (in the form of higher fuel and maintenance cost) to capital expenses (in the form of a more expensive purchase price). The result is that various costs are experienced at different points in the lifecycle of ICE vehicles versus electric drive vehicles. Therefore, this analysis compares the net present value of all of the costs incurred during the ownership lifecycle of a given vehicle. The items considered in the total cost of ownership calculation are made up of: Upfront (Capital) Costs to purchase the vehicle, battery, and charging infrastructure; Operating Costs that include fuel and/or energy, maintenance, repair and financing costs; and Residual Value of the vehicle (and battery where applicable).

Upfront (Capital) Costs
Upfront costs—or capital costs—include the cost of purchasing or leasing a vehicle. For grid-enabled vehicles, upfront costs also include the cost of purchasing or leasing the charging infrastructure required to support the vehicle. Finally, upfront costs are offset by the remodeled value of the vehicle and/or the residual value of the battery.

Chapter 3.4 contains four detailed case studies of TCO outputs for segments 1, 3a, 4a, and 5. Chapter 3.5 presents an analysis of the adoption potential of commercial and government fleet operators in the period 2010 to 2015. In particular, the uptake of electric drive technology—certainly PHEVs and EVs—will be extremely limited in some segments, such as long-haul delivery (segment 11). The utilization rates of these vehicles coupled with the type of routes traveled (relatively high percentage of highway miles) makes them unlikely near-term candidates for electrification. Other liquid fuel alternatives, such as biofuels derived from algae, might be potential options. Based on cost and technology, natural gas may also be a candidate to replace petroleum in long-haul delivery fleets.

Chapter 3.2 reviews the key modeling assumptions in detail. Chapter 3.3 presents the central summary-level findings of the modeling exercise across all segments. Chapter 3.4 contains four detailed case studies of TCO modeling the value of fuel savings over time. In general, higher mileage segments will benefit from the reduced operating costs of electric drive vehicles. Refueling behavior has a similar impact: vehicle segments identified in this analysis tend to have roughly similar refueling needs, which serve as the key driver of infrastructure costs for EVs and PHEVs.

Wherever possible, operational data used in this analysis was based on real-world data acquired from industry publications, data aggregators, and interviews with actual fleet operators. The segments identified for this analysis are presented in Figure 3C, which sorts them with actual fleet operators. The segments identified for this analysis were based on a number of market- and industry-wide costs and dynamics. These include: Upfront Vehicle Cost, Infrastructure Cost (charging), Petroleum Prices, Electricity Prices, Maintenance Cost, Vehicle and Battery Residual Value, and others.

In addition to the operational attributes of individual vehicle fleets, the total cost modeling was based on a number of market- and industry-wide costs and dynamics. These include: Upfront Vehicle Cost, Infrastructure Cost (charging), Petroleum Prices, Electricity Prices, Maintenance Cost, Vehicle and Battery Residual Value, and others.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>COST ELEMENTS</th>
<th>ICE</th>
<th>HEV</th>
<th>PHEV-40</th>
<th>EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>Vehicle (Powertrain excluding battery)</td>
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<td></td>
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<tr>
<td></td>
<td>Battery</td>
<td></td>
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<tr>
<td></td>
<td>Charger (includes installation and software)</td>
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<td></td>
<td>Residual Value</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Maintenance/Repairs (includes Oil, Tires, (-) Warranty)</td>
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<td></td>
<td></td>
<td>Low</td>
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<td>High</td>
</tr>
</tbody>
</table>

Note: High kWh Class vehicles have required significant increases in maintenance costs in early production versions of EVs due to both the nascent state of technology and the learning curve for repair technicians.

Source: PRTM Analysis.

Chapter 3.5 presents the results of the modeling exercise across all segments. The utilization rates of these vehicles coupled with the type of routes traveled (relatively high percentage of highway miles) makes them unlikely near-term candidates for electrification. Other liquid fuel alternatives, such as biofuels derived from algae, might be potential options. Based on cost and technology, natural gas may also be a candidate to replace petroleum in long-haul delivery fleets.
Base ICE Vehicles

Uptfront costs for the vehicles considered in this analysis vary by powertrain. In order to arrive at an estimate of vehicle capital cost, a sample internal combustion engine vehicle available in the market today was selected for each vehicle class. In general, the sample vehicles were among the top five models purchased by fleet operators in each class. For each sample vehicle, the individual drivetrain components were then assigned a cost value based on current market dynamics. ICE powertrain components include the engine, transmission, exhaust, fuel, and powertrain electronics. The base vehicle cost for each class then is calculated as the vehicle’s manufacturer suggested retail price (MSRP) minus all of the ICE powertrain components.

The cost of ICE drivetrain components used in this analysis increases at a 10-year compound average annual growth rate (CAGR) of 3.7 percent while electric drive-train components actually decrease at a 4.7 percent CAGR. Even though auto manufacturers are continuously reducing their direct materials, meeting increasingly stringent fuel-economy and emissions standards will likely continue to support rising ICE component costs.

Electric Drive Vehicles

The upfront cost of the various electric drive technologies includes additional components, such as some form of battery and electric motor. Depending on the drivetrain configuration—HEV, PHEV, or EV—the size of the battery and motor differ significantly. At the same time, each of the electric drive platforms benefits from downsizing or eliminating traditional ICE powertrain components to varying degrees. For example, a PHV may use a smaller engine in combination with a battery and electric motor, whereas an EV does not include an engine, fuel tank, or many other ICE components at all. In terms of cost, electric powertrain components tend to be more expensive than their ICE equivalents. Electric components include an electric motor, inverter, on-board charger, single-speed transmission, and powertrain electronics.

Increasing volumes of electric drive vehicles will drive costs of electric components down—at least over the timeframe considered in this analysis. That is, economies of scale achieved in the early stages of PHV and EV production will be significant factors, and falling costs will be a direct result of starting from a small unit volume base. This analysis assumes the cost profiles displayed in Figure 3G.

Charging Infrastructure

The charging infrastructure associated with grid-enabled vehicles can represent a significant portion of the upfront costs. On a per-vehicle basis, charger costs will often be much less than the combined cost of the necessary electric drivetrain components; however a fleet operator seeking to electrify multiple vehicles may need to invest in multiple chargers. Moreover, certain fleet applications will require multiple chargers per vehicle—some at the depot and some in public—or may require use of fast chargers.

This analysis considers five possible infrastructure configurations as detailed in Figure 3F. Individual configurations are essentially a function of the operational needs of the vehicles themselves, and each configuration is characterized by a different ratio of charging in public versus at the depot. Each fleet application considered in the analysis was assigned a specific infrastructure configuration, and a cost was assigned based on the cost of the associated chargers, their installation, and any additional IT capabilities required to manage and optimize vehicle charging.

Operating Costs

Operating costs are those costs associated with fueling and maintaining a given vehicle over its useful life. Operating costs may vary significantly based on the cost of fuel (gasoline, diesel, or electricity), the efficiency with which the energy is used, and the way the vehicle is operated.

Energy Prices

Energy prices for this analysis were taken from the U.S. Department of Energy’s Annual Energy Outlook 2010. For traditional internal combustion engine vehicles, HEVs, and PHEVs in charge-sustaining mode, the relevant energy prices are either gasoline or diesel fuel (depending on vehicle class). For EVs and PHEVs in charge-depleting mode, the relevant energy price is electricity. Depending on the applicable fleet industry segment, vehicles may be charged at residential, commercial, or industrial electricity rates. As discussed in Part One of this Roadmap, commercial and industrial consumers benefit from significantly reduced electricity prices.
It is important to note that DOE scenarios do not account for the considerable price volatility of retail petroleum fuels. National average gasoline and diesel prices today are at $2.77 and $3.07 per gallon respectively. As recently as 2008, they were each as much as 30 to 50 percent more expensive. Given current global oil market dynamics, it would be reasonable to expect the fuel component of the ICE vehicle equation to fluctuate considerably more than DOE’s scenarios indicate—though that has not been incorporated into the reference case in this analysis. Still, the business benefits from electric vehicles will depend considerably on how quickly and how much the price of these fuels increases. (For an analysis of the sensitivity of ownership costs to fuel fluctuations, see Chapter 3.3.)

The principal costs associated with electricity prices involve generation and transmission assets, not fuel, so electricity prices do not fluctuate considerably over the forecast period. Efforts to regulate greenhouse gas emissions from the electric power sector could represent one potential upside risk to long-term electricity prices. However, these price increases are likely to be phased in slowly, and most of the current proposals being considered by Congress would not significantly impact electricity prices before 2020.1

Energy Consumption Rates
The efficiency with which a given vehicle consumes energy has a significant impact on its lifecycle operational costs. For internal combustion engine vehicles—as well as HEVs and PHEVs in charge-sustaining mode—energy efficiency is measured in terms of miles traveled per gallon of fuel consumed (mpg). For EVs and PHEVs in charge-depleting mode, energy efficiency is measured in terms of miles traveled per kWh consumed (mi/kWh).

Wherever possible, the energy consumption rates for internal combustion engine vehicles in this analysis were calculated using observed fuel efficiency rates as opposed to the sticker rate or fuel-economy rating associated with EPA driving cycles. These fuel consumption rates were acquired using real world data provided by fleet operators, industry publications, automotive intelligence companies, and other sources. In the case of select segments with high idling applications, an additional engine idling efficiency loss factor of a maximum of 10 percent was applied. HEVs were assumed to provide energy efficiency gains estimated at 30 percent over ICE fuel efficiency ratings.

For EVs and PHEVs in charge-depleting mode, there is not yet a rich data set that allows for use of real world data. Over the period 2010 to 2020, this analysis was based on the charge-depleting efficiency levels displayed in Figure 3K.

Maintenance and Repairs
Maintenance and repair expenses for internal combustion engine vehicles can include motor oil, tires, scheduled maintenance, and warranty recovery (a negative expense). The proportion of each cost changes over time. Motor oil, tire replacement and other scheduled maintenance expenses remain relatively steady during the life of the vehicle. However, other repairs related to wear and tear and component replacement may increase over the life of the vehicle. Oil and tire costs are projected to grow slightly due to engine and chassis wear. Repair costs are projected to grow over the first 10 years of vehicle life by an annual rate of 22 percent. The bulk of that cost is logged in the later years, after significant mileage milestones are eclipsed. In general, medium- and heavy-duty trucks cost more per mile to maintain than autos and class 1-2 trucks.

Electric powertrains bring a reduction in scheduled maintenance and repairs compared to traditional ICE vehicles. Internal combustion engine components are hundreds of thousands of moving parts that degrade over time. Electric motors are much simpler and will not require the same amount of maintenance and repair. Maintenance and repair savings from electrification were calculated by estimating ICE maintenance and repair costs and then applying a savings factor that varies based on drivetrain configuration. Figure 3M displays the maintenance discount factors associated with HEV, PHEV and EV drive-trains. (Note: EVs offer the most significant maintenance savings, as the design is the most technically simple. The savings associated with HEVs can vary somewhat depending on duty cycle. Data used in this report is based on industry expectations.)

### Figure 3H: Retail Fossil Fuel Prices (2010-2020)

- **2010:** $3.07 per gallon
- **2015:** $3.98 per gallon
- **2020:** $4.00 per gallon

### Figure 3I: Retail Electricity Prices (2010-2020)

- **2010:** $0.14 per kWh
- **2015:** $0.16 per kWh
- **2020:** $0.18 per kWh

### Figure 3J: PHEV Charge-Depleting Range Utility Factor (%)

- **Gen. Cars:** 4.0
- **Class 1-2:** 3.1
- **Class 3:** 2.2
- **Class 4-5:** 1.5
- **Class 6-7:** 1.2

### Figure 3K: Electric Motor Efficiency

- **Light Sales/Service:**
  - Utility Cars: 0.40
  - Service, Utility, Gov.: 0.35
  - Car Sharing: 0.30
- **Medium & Heavy:**
  - Heavy Utility, Gen.: 0.18
  - Heavy Utility, Gov.: 0.15

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1. DOE, EIA, Petroleum Navigator, Weekly Retail Gasoline and Diesel Prices (October 25, 2010)
2. DOE, AER 2009, Table 5.24

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1. DOE, EIA, Petroleum Navigator, Weekly Retail Gasoline and Diesel Prices (October 25, 2010)
2. DOE, AER 2009, Table 5.24
Ownership Model

While different vehicle ownership models can have a significant impact on a given institution’s ability to adopt electric drive vehicles, the benefits of alternative financing methods do not factor into the TCO calculation. Leasing a vehicle may minimize upfront capital costs associated with vehicle acquisition, but the lifecycle total cost of ownership on a per mile basis should be equal to or more than the TCO for a vehicle that is owned outright. Therefore, a simplifying assumption that a company’s capital costs equal financing costs is made in the model. A financing rate of 6 percent on the capital cost should be equal to or more than the TCO for vehicle acquisition, but the lifecycle total cost of ownership may minimize upfront capital costs associated with vehicle ownership.

Residual Value

Fleet owners in different industry segments—and across different companies within an industry segment—hold on to their vehicles for varying lengths of time. The length of time that vehicles are owned and the ending mileage largely determine the remaining value of the vehicle. In essence, this residual value is a negative cost or a credit for the capital that is not consumed during the operation of the vehicle. For fleet operators that tend to hold on to their vehicles for shorter timeframes, the residual value of their assets is a larger, more significant component of the total cost of ownership. For ICE vehicles, this residual value is easily attainable, as there are a number of well-established precedents and a liquid and efficient market to price them. Fleet owners can analyze the trade-offs between selling their vehicles at their current residual value against maintaining them for longer periods based on expected maintenance costs, prices of new vehicles, availability of capital, vehicle demand, and softer factors such as image and brand.

Electric drive vehicles—particularly EVs and PHEVs—pose a new challenge because their residual value is not well known. For this reason, this analysis treats the residual value calculation for the vehicle and the battery separately.

Vehicle Depreciation Rates

The rate of depreciation is the decline in value associated with an asset over a given period of time. It is important to realize that the depreciated financial value of an asset at any point in time may be significantly different than the remaining technical capacity. For example, the assessed market value of an internal combustion engine vehicle after 10 years and 100,000 miles may be a small fraction of the initial purchase price despite the fact that the vehicle may have the technical capacity to operate for another 100,000 miles.

The standard depreciation curve for an internal combustion engine vehicle is therefore characterized by a steep decline in the initial period after ownership with the rate of decline slowing over time. The starting point for the depreciation curve may vary based on the cumulative number of miles traveled by the vehicle. Figure 3M presents a standard set of depreciation curves for an ICE vehicle used in this analysis. The depreciation curves include a time and distance factor to account for different usage scenarios.

This analysis assumes a depreciation curve for electric drive vehicles—including the battery—in the same way that a traditional ICE vehicle’s depreciation values might be calculated. If a separate depreciation schedule were calculated for electric drive vehicles, one might expect electric drive components to generate a higher residual value than their ICE counterparts, as they will tend to incur lower maintenance and repair expenses and, in all likelihood, an increased asset life. However, there is simply not enough market experience dealing with remarked electric drive vehicles to confidently plot a separate depreciation schedule for these vehicles. The residual value of electric drive vehicles is generally uncertain today.

Battery Depreciation

The principal driving factor behind uncertainty in electric drive residual value is the battery. Electric drive batteries—particularly for PHEVs and EVs—constitute a significant proportion of the vehicle’s upfront cost, so the total cost of ownership calculation is highly sensitive to the residual value of the battery. Ideally, this value would be determined by the number of cycles left in the battery at the end of the vehicle’s useful life. However, significant uncertainties remain (as discussed in Part Two).

The residual value of used PHEV and EV batteries will be determined by the net residual capacity (the sum of each remaining cycle’s capacity) multiplied by the battery’s value of that capacity. For the purposes of this analysis, it was conservatively assumed that GHEV batteries decline in value in a fashion similar to vehicles themselves (i.e., the curve shape in Figure 3M). Residual value exceeds the financial depreciated value but falls below the cost of comparable new battery. For cases in which ownership of the vehicle outlasts the useful life, it is assumed that a replacement battery with a lower useful life would be purchased at a discounted price to the original battery.
CHAPTER 3.3

Key Findings

Based on expected trends in battery and electric drive component costs as well as mainstream expectations regarding energy costs, electric drive vehicles should prove highly attractive to fleet operators in the coming years.

Electric drive vehicles are cost competitive in a number of fleet applications today—even when assuming no access to government subsidies and no change in purchasing or usage patterns (the base case). In fact, traditional HEVs are a cost-effective replacement for ICE vehicles by 2012 in most of the segments where driving distance exceeds 20,000 miles per year. This is a result of the relatively small incremental investment for an HEV compared to an ICE vehicle. GEVs begin to emerge as the most cost effective solution between 2015 and 2028 as battery costs fall to fall below $4,000/kWh. Base case competitiveness timelines are presented in Figure 3O.

It is important to note that the deployment of HEVs can be beneficial for PHEVs and EVs, assuming that HEV batteries migrate toward lithium-ion and other battery chemistries that are utilized in grid-enabled vehicles. By driving volume in the manufacture of battery cells and other components, HEVs can help facilitate the reduction in costs that will make EVs and PHEVs a compelling option. Ultimately, however, PHEVs and EVs clearly represent the most compelling opportunity to reduce petroleum consumption in the transportation sector.

The cost effectiveness timeline for each of the electric drive vehicle technologies is improved by optimizing the GEV ownership duration to coincide with the battery life; and right-sizing EV batteries to meet the needs of low mileage fleet applications.

These two actions would advance the time required for PHEVs and EVs to become the most cost effective solutions by approximately one year in a number of segments. Figure 3P presents the competitiveness timelines for the optimized case.

While not considered here, it is important to note that other methods of optimization could improve EV and PHEV competitiveness timeframes. For example, some OEMs are designing more efficient vehicles that can maximize efficiency in a given class. Light-weight vehicle materials combined with improved aerodynamics can increase the number of miles traveled per kWh of battery capacity, further facilitating right-sizing. Such innovative design approaches would significantly improve the value proposition of EVs and PHEVs.

Finally, when current and potential future GEV government incentives are considered, the cross-over point for GEV cost parity is reached within the next two to three years in all of the commercial segments. The incentives assumed for this analysis include $7,500 federal tax credits applied for GEV passenger car and class-1-2 trucks; $15,000 tax credits applied to class 3 medium-duty trucks; $20,000 tax credits applied to class 4-5 medium-duty trucks; and $25,000 tax credits applied to class 6-7 heavy-duty trucks. The full credits are available through 2015, after which they are ramped down annually until they reach zero in 2020.

In all cases, this analysis implies a progression in cost competitiveness from ICE, through HEV, to PHEV-40 and EV-100. Fleet owner behavior and public policy can have a dramatic impact on the rate of that progression, but rising fuel costs coupled with falling electric drive component costs suggest that PHEVs and EVs will increase in competitiveness over time in nearly all fleet segments.

### FIGURE 3O
**Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized**

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<tr>
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### FIGURE 3P
**Lowest TCO Drivetrain Technology by Year and Segment – Case (No Policy Incentives)**

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### FIGURE 3T
**Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized + Government Incentives**

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Source: PRTM Analysis
Critical Sensitivities Impacting TCO

There are a number of non-policy related economic and behavioral factors that will influence the ultimate cost of ownership of electric drive vehicles. In particular, however, three factors stand out: battery cost, gasoline price, and annual driving distance.

Because battery cost represents such a significant portion of vehicle cost, this analysis implies that an EV purchased in 2015 will have approximately 30 percent in total ownership cost savings with respect to an ICE vehicle if the battery cost is reduced by just 10 percent versus the base case.

Gasoline (or diesel) expense constitutes more than two-thirds of the average operating cost for nearly any given fleet. A 10 percent increase in petroleum fuel price (while holding electricity prices constant) results in an approximate 30 percent reduction in EV ownership costs with respect to ICE total ownership costs. All of the electric drive technologies are more competitive in a higher fuel-price environment.

Annual driving distance becomes a key factor due to the significantly higher initial investment required by electric drive compared to ICE vehicles. Without sufficient annual driving distance, the future energy cost and maintenance cost savings are insufficient to offset the initial investment.

Combined Impact of Battery Cost and Gasoline Price

Of the three key factors that have the greatest impact on the business case, battery cost and fuel expense are both out of the control of operators and will have a significant impact upon whether GEVs are financially attractive to the operators. To assess this, two additional scenarios around the base scenario were considered: a Pessimistic Case (2020 Battery Cost +15%, 2010-2020 Fuel Cost -15%) and an Optimistic Case (2020 Battery Cost -15%, 2010-2020 Fuel Cost +15%). As shown in the three scenarios, a shift from the Pessimistic Scenario to the Optimistic Scenario drives a four-year shift in the point at which GEVs become the lowest cost vehicle to own.

Annual Driving Distance “Sweet Spot”

In general, the higher the annual driving distances, the lower the TCO for an electric drive vehicle with respect to an ICE for a vehicle purchased in 2018. This is due to the realization of faster energy and maintenance cost savings, resulting in an acceptable payback period. An example of this for segment 1 (sales, service, and utility automobiles) is shown in Figure 3R. In this segment, an annual driving distance of 6,000 miles per year results in a $0.08 per mile ownership cost gap for an EV with respect to an ICE for a vehicle purchased in 2018. For an application where the annual driving distance exceeds 15,000 miles per year, the EV ownership costs reach parity with an ICE over the standard ownership period for the segment of six years.

While the ownership costs decrease as annual mileage is increased from low to moderate levels, there are also operating limitations that will begin to increase ownership costs as mileage increases. For example, fleet applications where the driving distance exceeds 100 miles per day will require a significant amount of daytime charging. This adds both increased energy costs incurred for peak electricity rates as well as infrastructure costs.

Due to infrastructure and vehicle cost differences between the different segments, the optimal driving distance will vary by segment. At the same time, the optimal distance will decrease by year as technology costs fall.
Focus on Battery Right-Sizing

Due to the high cost of batteries relative to other electric drivetrain costs, battery cost optimization will receive attention from manufacturers and fleet operators alike. Significant effort is already being dedicated to reducing the material, manufacturing, and logistics costs of large-format batteries. In addition to these technological improvements, however, practical steps can be taken by industry participants to minimize cost.

Operators of fleet segments that do not fully utilize the maximum available capacity of EV and PHEV batteries will likely work with battery manufacturers to optimize battery size for their required driving range. For example, in a low mileage segment such as segment 2 (government cars), the daily driving range is less than 40 miles, but available EVs are likely to provide 100-mile range capability. The 60 percent unused battery capacity becomes too expensive to offset through electricity cost savings until battery costs drop below $300/kWh. However, if this segment were given the option of purchasing an EV with a 60-mile driving range, the vehicle cost savings would exceed $4,000 in 2015. As a result, an EV could reach ownership cost parity with an ICE or HEV three years sooner than in the base case. Offering fleet specific configurations is commonly done today and would be a key enabler for making the economics of EVs and PHEVs work for different fleet segments sooner.

Base Case

The Base Case assumes that operators purchase vehicles being offered in the market today at current specifications. An operator makes no behavioral changes to reduce cost. Public policy is not considered in the Base Case. Operators do not benefit from existing or future subsidies.

Optimized + Policy Case

The Optimized + Policy Case assumes that fleet operators can purchase vehicles that fit their needs and that they will use them in the manner that most efficiently lowers cost. Battery right-sizing and extended ownership periods are examples of optimized use. The Optimized + Policy case also incorporates existing federal government tax incentives for light-duty vehicles and assumes additional subsidies not currently in law for medium- and heavy-duty trucks.

Case Studies

The following case studies consider vehicle TCO in two cases: a base case and optimization + policy case. Both cases are based on mainstream, consensus industry cost data outlined in Chapter 3.2 and energy prices from the reference case in the Department of Energy’s Annual Energy Outlook 2010. The key scenario attributes are as follows:

Base Case

The base case assumes that operators purchase vehicles being offered in the market today at current specifications. An operator makes no behavioral changes to reduce cost. Public policy is not considered in the base case. Operators do not benefit from existing or future subsidies.

Optimized + Policy Case

The optimized + policy case assumes that fleet operators can purchase vehicles that fit their needs and that they will use them in the manner that most efficiently lowers cost. Battery right-sizing and extended ownership periods are examples of optimized use. The optimized + policy case also incorporates existing federal government tax incentives for light-duty vehicles and assumes additional subsidies not currently in law for medium- and heavy-duty trucks.
CASE STUDY / SEGMENT 1

Sales, Service, Utility Cars

Segment 1 vehicles—sales, service, and utility automobiles—are typically operated by single drivers such as sales people, service employees, and utility employees. Their average daily driving distance is approximately 71 miles and, while they don’t have fixed routes, they do tend to stay within a consistent proximity to their base. Unlike segments in which the vehicles are in operation for most of the day, this segment tends to have longer periods of time when the vehicles are parked (during sales meetings, service calls, and overnight, for example).

VEHICLE CHARACTERISTICS

- 4-Door, 5-Passenger Car
- Typical Track Space: 16 cm. ft.
- Typical Dimensions: 190” x 85” x 55” (WxLxH)
- Gross Vehicle Weight: Up to 6,000 lbs.
- Typical Passenger Volume: 100 ft³

OPERATIONAL SPECIFICATIONS

- 71 miles (Average Distance Segment Traveled Each Day)
- 6 years (Average Ownership Duration)
- $3,800 (Average Infrastructure Cost Per Vehicle)

INFRASTRUCTURE TOPOLOGY

- Service Area: 4-Door, 5-Passenger Car
- Charge Depleting Range: 40 miles
- Fast Charger: 5 kW
- On-Board Charger: 8 kW
- Home Charger: 1 kW

Vehicle Specifications

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<td>On-Board Charger Cost</td>
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Total Cost of Ownership (Base Case)

Due to the relatively high mileage of the segment, a positive payback on the greater initial investment of an electric drive vehicle is achieved earlier than fleet segments that have lower annual mileage. As shown in Figure 3W, the HEV is the first electric drive vehicle to achieve TCO parity with an ICE vehicle, doing so in approximately 2011.

As battery and other electric drivetrain component costs come down, the price of these vehicles is expected to decrease significantly. In the case of an EV, expected cost reductions will result in the vehicle price decreasing from approximately $41,000 today to approximately $33,000 in 2020 (excluding any federal or local incentives). At the same time, the technology required for an ICE to meet emissions and fuel economy requirements will add approximately $2,000 to the base vehicle configuration by 2020 due to the addition of advanced engine technologies such as boosting, direct injection, electric valve actuation, and advanced transmissions.
productivity-driven improvements expected over the same period, resulting in an ICE vehicle price increase from $26,300 in 2010 to approximately $28,000 by 2020. At the same time, while the base ICE fuel economy is likely to increase by almost 40 percent by 2020, nominal fuel prices are expected to increase from $2.57 per gallon in 2010 to $4.08 per gallon in 2020. As a result, by approximately 2016 the PHEV-40 reaches total cost parity with an ICE vehicle. By 2018, reduced electric drive component costs—which represent a much larger portion of the total vehicle cost in EV and PHEV-40 than in HEV—will result in an overall TCO advantage for EV and PHEV-40 when compared to an HEV.

Operational Variables

While many of the factors influencing ownership costs are out of a fleet operator’s control, there are some factors that can be adjusted to optimize electric drive operating costs. One of the most significant factors is ownership duration. For segment 1, vehicles are typically owned for as long as six years (though there are significant variances within this average). This is largely driven by maintenance and repair costs that begin to increase significantly as vehicles approach 150,000 miles. As a result, an ICE vehicle. By 2018, reduced electric drive component costs—which represent a much larger portion of the total vehicle cost in EV and PHEV-40 than in HEV—will result in an overall TCO advantage for EV and PHEV-40 when compared to an HEV.

Policy Variables

The total cost of ownership in the base case does not include the current federal tax incentives of $7,500 per vehicle. When this is factored in, GEVs become financially attractive for segment 1 fleet operators almost immediately. As shown in Figure 3Y, the total cost of ownership with government incentives along with the operational optimizations described previously reaches parity with an HEV and PHEV-40 before 2012, and for an EV before 2015.

Light Sales, Service, Utility, Short Haul

Segment 3a vehicles—light sales, service, utility, and short-haul trucks—are typically pooled vehicles operated by sales people, service employees, utility employees, and short-haul delivery company employees. Their average daily driving distance is 75 miles and they tend to stay within a consistent distance from the depot at which they are left overnight. The consistency of the routes varies between applications within segment 3a. It can be very consistent in segments such as short haul and highly variable in segments such as utility.

Operational Specifications

At 75 miles, the average distance traveled by this segment in a calendar year is more than 40,000 miles, which is high enough to drive a relatively long predicted in segment 1. The extended cab capacity of 5 passengers. The vehicles are returned to a central depot at the end of each day where they can be charged overnight. The vast majority of the charging requirements for these vehicles are likely to be supported by overnight Level II charging. Daytime charging away from the depot is rarely required as these vehicles and not typically driven farther than the CD range of an EV-100.

Infrastructure Topology

Central depot

Public charging

Home charging

Central charging depot rank

Fast chargers

Home chargers

INFRASTRUCTURE TOPOLOGY

At seven years, the average ownership duration for this segment would likely necessitate battery replacement. The timing of battery replacement can have a significant impact on TCO.

Vehicle Characteristics

Class 1-2 Truck

Typical Cargo Volume: 40 ft³

Gross Vehicle Weight: 6,000–10,000 lbs.

Extended Cab Capacity: 5 Passengers

Operational Variables

While many of the factors influencing ownership costs are out of a fleet operator’s control, there are some factors that can be adjusted to optimize electric drive operating costs. One of the most significant factors is ownership duration. For segment 1, vehicles are typically owned for as long as six years (though there are significant variances within this average). This is largely driven by maintenance and repair costs that begin to increase significantly as vehicles approach 150,000 miles. As a result, six years/130,000 miles is the point that this segment typically replaces its vehicles.

For an EV, the expected non-battery service and maintenance costs are significantly lower than for an ICE vehicle due to reduced mechanical complexity. As a result, ownership cycles in excess of six years may be feasible for EVs in segment 1. However, the optimal ownership period

will be closely related to the battery replacement timing. With the current assumption of an EV battery life set at 125,000 miles, the replacement timing will be approximately every five years for segment 1. Since the battery will depreciate quickly in the first two to three years, the optimal point to transfer ownership of the vehicle is right before a replacement battery is required. The least cost-effective period to transfer ownership is right after a new battery has been purchased (approximately six years in segment 2). Extending EV ownership in this segment from six to nine years will decrease EV ownership costs by approximately $0.07 per mile—a cost that includes the price to replace the battery in year five. The extended ownership period reduces the time that it takes for EVs to reach cost parity with ICE vehicles by approximately one year.

Policy Variables

The total cost of ownership in the base case does not include the current federal tax incentives of $7,500 per vehicle. When this is factored in, GEVs become financially attractive for segment 1 fleet operators almost immediately. As shown in Figure 3Y, the total cost of ownership with government incentives along with the operational optimizations described previously reaches parity with an HEV and PHEV-40 before 2012, and for an EV before 2015.
Total Cost of Ownership (Base Case)

The annual driving distance of approximately 19,000 miles for vehicles within this segment is sufficient to reach the “sweet spot” in the operating cost curve. In the base case, HEV becomes the most cost effective technology in approximately 2011. Following this, EV will achieve cost parity with HEV in approximately 2018, driven by component cost reductions and gasoline price increases. Between 2010 and 2018, the EV vehicle price will decrease by approximately $8,000 while the HEV price decreases by approximately $1,000. Meanwhile, the lifetime energy costs for the EV increase by $100 between 2010 and 2018 while the lifetime energy costs for the HEV increase by approximately $2,000 over the same period.

Operational Variables

As is the case with segment 1, the typical ownership duration for ICE will likely need to be adapted for operation of EVs. The typical ownership period for this segment is seven years/130,000 miles. With an EV battery replacement interval of 125,000 miles, an ownership period of seven years will result in vehicle remarketing shortly after replacing the battery. This results in a residual loss that will increases total ownership cost. To avoid this, operators will likely opt for extending the ownership period to be near the end of life for the second battery. By extending the ownership period to 10 years, the total EV ownership costs in 2018 are reduced by approximately $0.05 per mile while the 2018 HEV ownership costs are only reduced by approximately $0.04.

Policy Variables

While the long-term outlook for EV costs in segment 3 looks promising compared to the other drivetrain technologies, there will still be a need for early incentives to stimulate demand and supply of plug-in light trucks. To assess the impact of these potential incentives on the ownership cost, it has been assumed that class 1-2 trucks will have a similar incentive structure to passenger cars, with a $7,500 tax credit. The impact of this $7,500 tax credit combined with the operational changes described in the previous section is shown in Figure 3AA. The net impact of these changes is that there is a net cost of ownership advantage for PHEV-40 by 2012 and EV by 2014.

Vehicle Specifications

<table>
<thead>
<tr>
<th>ICE 2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Drivetrain</td>
<td>4.3L Gas / 2WD Auto</td>
</tr>
<tr>
<td>Base Engine Cost</td>
<td>$2,030</td>
</tr>
<tr>
<td>Base Transmission Cost</td>
<td>$1,800</td>
</tr>
<tr>
<td>Exhaust System Cost</td>
<td>$940</td>
</tr>
<tr>
<td>Fuel System Cost</td>
<td>$940</td>
</tr>
<tr>
<td>Mandated Fuel Efficiency Improvements (% of MPG increase)</td>
<td>$120</td>
</tr>
<tr>
<td>Fuel Economy</td>
<td>16 MPG</td>
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<table>
<thead>
<tr>
<th>PHEV 2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Drivetrain</td>
<td>PHEV-40</td>
</tr>
<tr>
<td>Electric Range</td>
<td>40 mi</td>
</tr>
<tr>
<td>Battery Cost</td>
<td>$660</td>
</tr>
<tr>
<td>Battery Size</td>
<td>14.3 kWh</td>
</tr>
<tr>
<td>Battery Life</td>
<td>150,000 mi</td>
</tr>
<tr>
<td>Electric Motor Cost</td>
<td>$1,188</td>
</tr>
<tr>
<td>Inverter Cost</td>
<td>$1,944</td>
</tr>
<tr>
<td>Charger Size</td>
<td>4 kW</td>
</tr>
<tr>
<td>On-Board Charger Cost</td>
<td>$693</td>
</tr>
<tr>
<td>HEV 2010</td>
<td>2020</td>
</tr>
<tr>
<td>Battery Cost</td>
<td>$1,200</td>
</tr>
<tr>
<td>Battery Size</td>
<td>1.8 kWh</td>
</tr>
<tr>
<td>Battery Life</td>
<td>200,000 mi</td>
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<tr>
<td>Electric Motor Cost</td>
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</tr>
<tr>
<td>Inverter Cost</td>
<td>$1,512</td>
</tr>
<tr>
<td>EV-100 2010</td>
<td>2020</td>
</tr>
<tr>
<td>Battery Cost</td>
<td>$600 /kWh</td>
</tr>
<tr>
<td>Battery Size</td>
<td>29 kWh</td>
</tr>
<tr>
<td>Battery Life</td>
<td>125,000 mi</td>
</tr>
<tr>
<td>CD Range Efficiency</td>
<td>3.1 mi/kWh</td>
</tr>
<tr>
<td>Electric Motor Cost</td>
<td>$1,188</td>
</tr>
<tr>
<td>Inverter Cost</td>
<td>$1,944</td>
</tr>
<tr>
<td>Charger Size</td>
<td>6 kW</td>
</tr>
<tr>
<td>On-Board Charger Cost</td>
<td>$1,050</td>
</tr>
</tbody>
</table>

Source: PRTM Analysis
CASE STUDY / SEGMENT 4A

Light Government

Segment 4a vehicles—government light trucks—are typically pooled vehicles operated by federal, state, and local government employees. Their average daily driving pattern consists of a driving distance of 22 miles originating at a government depot and following a route that is typically highly predictable. A typical application would be a pickup truck used by department of transportation employees to travel between different road construction sites.

VEHICLE CHARACTERISTICS

Class 1-2 Truck

Typical Cargo Volume: 60 cu ft

Gross Vehicle Weight: 6,000-10,000 lbs.

Extended Cab Capacity: 5 Passengers

OPERATIONAL SPECIFICATIONS

22 mi

Average Distance Traveled Each Day

10 Years

Average Ownership Duration

$3,400

Infrastructure Cost Per Vehicle

INFRASTRUCTURE TOPOLOGY

Central Charger Depot Bank

Public Charger

Fast Charger

Home Charger

Charge Depleting Range

Service Area

Total Cost of Ownership (Base Case)

The annual mileage of approximately 6,000 miles per year for segment 4a requires significant reductions in GEV drivetrain costs to become cost effective compared to ICE. In 2010, the incremental vehicle price for an EV is almost $18,000. Meanwhile, because of the low annual mileage, the discounted lifetime energy and maintenance cost savings for the EV are approximately $4,500. By 2020, the net ownership cost of an EV is nearly on par with the ICE ownership costs. This is largely driven by the incremental EV purchase price decrease of approximately $11,000 and the EV energy and maintenance cost savings increase to $5,800. It is not until 2022 that the operating cost savings are sufficient to fully offset the incremental vehicle costs as well as the other infrastructure costs incurred for an EV.

Operational Variables

Despite the low annual mileage of this segment, it is unlikely that the typical ownership duration of 10 years will be extended for GEVs despite the fact that the electric drivetrain will not be approaching its useful life. As a result, this will not likely be an area requiring operational optimization as in the commercial segments. The area

Vehicle Specifications

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE</td>
<td>Base Engine</td>
<td>4.3L Gas / 2WD Auto</td>
</tr>
<tr>
<td></td>
<td>Base Engine Cost</td>
<td>$2,030</td>
</tr>
<tr>
<td></td>
<td>Base Transmission Cost</td>
<td>$1,800</td>
</tr>
<tr>
<td></td>
<td>Exhaust System Cost</td>
<td>$840</td>
</tr>
<tr>
<td></td>
<td>Fuel System Cost</td>
<td>$140</td>
</tr>
<tr>
<td></td>
<td>Battery Cost</td>
<td>$0</td>
</tr>
<tr>
<td></td>
<td>Battery Range</td>
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</tr>
<tr>
<td></td>
<td>Battery Life</td>
<td>10 years</td>
</tr>
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<td></td>
<td>Electric Motor Cost</td>
<td>$1,188</td>
</tr>
<tr>
<td></td>
<td>Inverter Cost</td>
<td>$1,944</td>
</tr>
<tr>
<td></td>
<td>Charger Size</td>
<td>4 kW</td>
</tr>
<tr>
<td></td>
<td>On-Board Charger Cost</td>
<td>$693</td>
</tr>
<tr>
<td></td>
<td>CD Range Efficiency</td>
<td>3.1 mi/kWh</td>
</tr>
<tr>
<td>HEV</td>
<td>Base Engine</td>
<td>4.6L Gas / 2WD Auto</td>
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<tr>
<td></td>
<td>Base Engine Cost</td>
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<td>Base Transmission Cost</td>
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<td>Exhaust System Cost</td>
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<td>Battery Range</td>
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<td></td>
<td>Electric Motor Cost</td>
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<td></td>
<td>Inverter Cost</td>
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<tr>
<td></td>
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<td></td>
<td>On-Board Charger Cost</td>
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<tr>
<td></td>
<td>CD Range Efficiency</td>
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<td>PHEV-40</td>
<td>Base Engine</td>
<td>4.3L Gas / 2WD Auto</td>
</tr>
<tr>
<td></td>
<td>Base Engine Cost</td>
<td>$2,030</td>
</tr>
<tr>
<td></td>
<td>Base Transmission Cost</td>
<td>$1,800</td>
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<td></td>
<td>Exhaust System Cost</td>
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</tr>
<tr>
<td></td>
<td>Fuel System Cost</td>
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</tr>
<tr>
<td></td>
<td>Battery Cost</td>
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</tr>
<tr>
<td></td>
<td>Battery Range</td>
<td>40 mi</td>
</tr>
<tr>
<td></td>
<td>Battery Life</td>
<td>150,000</td>
</tr>
<tr>
<td></td>
<td>Electric Motor Cost</td>
<td>$1,188</td>
</tr>
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<td></td>
<td>Inverter Cost</td>
<td>$1,944</td>
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<tr>
<td></td>
<td>Charger Size</td>
<td>4 kW</td>
</tr>
<tr>
<td></td>
<td>On-Board Charger Cost</td>
<td>$693</td>
</tr>
<tr>
<td></td>
<td>CD Range Efficiency</td>
<td>3.1 mi/kWh</td>
</tr>
</tbody>
</table>

Source: PRTM Analysis
that requires optimization for cost effective operation in this segment is the battery capacity. Based on current offerings, it was expected that the base vehicle will be designed with a 100-mile charge-depleting range. However, in this segment, the typical driving distance is only 22 miles per day. After applying a 66 percent margin to allow for charge depletion and driving distance variability, the segment would still only require a battery large enough to provide a charge depletion range of approximately 36 miles. If a fleet specific offering were developed with a CD range suited to a 40 mile range application, the battery capacity would be reduced by 60 percent, which would result in a battery cost reduction for EVs of approximately $10,000 in 2010, which would have a dramatic impact on the total cost of ownership. As shown in Figure 3CC, making this change would enable EVs to be the most cost effective drivetrain by 2015, a decrease of approximately six years from the base case. Such a change would also significantly differentiate EV from the PHEV-40 since the EV has the same battery capacity without having to carry the cost of the ICE powertrain.

**Policy Variables**

No monetary incentives are currently assumed for this segment. However, policy recommendations contained in Part Four of this report would make incentives available to federal, state, and local government agencies.

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**CASE STUDY / SEGMENT 5**

Medium Short Haul, Sales & Service

Segment 5 vehicles—medium duty, short haul, sales and service trucks—are used for hauling heavier loads for a variety of applications. These are typically higher mileage vehicles with driving distances averaging around 100 miles per day. Most applications will originate from a depot and will typically have at least eight hours of non-operating time at the depot every day. A common application in segment 5 is a delivery vehicle.
Total Cost of Ownership (Base Case)

The high annual mileage of 30,000 miles per year of the medium duty, short haul, sales and service segment results in GEVs reaching ownership cost parity among the fastest of any of the fleet segments analyzed. As shown in Figure 3DD, EVs achieve ownership cost parity with ICEs by 2015 and with HEVs by 2016. More than the previous three cases studied, batteries become the central part of the business case. In this segment, the 2010 purchase price for an EV is approximately $47,000 higher than the initial purchase price of the ICE. Over the 10 year ownership period of the typical vehicle in this segment, the discounted energy savings of the EV purchased in 2010 are approximately $45,000. Additionally, over this same period, the discounted maintenance and repair costs excluding battery replacement are $13,000 lower for an EV compared to an ICE vehicle. However, when battery replacement is included, an additional $49,000 of discounted future battery replacement expenses need to be included for the two additional batteries required over the 10 year, 300,000 mile ownership period. At the end of this ownership period, the net present value of the ownership cost gap of an EV purchased in 2010 compared to an ICE purchased at the same time is approximately $33,000.

By 2015, when the EV reaches cost parity with an ICE, the purchase price difference decreases from $47,000 to $30,000. The reduction in battery costs, which was largely responsible for the initial vehicle cost reduction, also enables reduced replacement battery costs for vehicles purchased in 2015 (from $49,000 to $34,000). As in the other case examples, the rising fuel costs also drive a significantly larger energy cost savings for the EV purchased in 2015 increasing from $45,000 to $50,000. Overall, in 2015, an ICE and EV have comparable ownership costs of approximately $156,000 over the ten year ownership period.

Operational Variables

In this segment, optimizing the ownership duration will have a less prominent impact than in some of the other segments. With the ownership period of segment 5 vehicles typically around 10 years/300,000 miles, it is unlikely that many fleet operators will want to extend the period much further. However, if they did, the net impact would not have a material impact on the purchase decision. The ownership costs for both ICE and EV would decrease a comparable amount.

Policy Variables

As with passenger cars, incentives could have a significant impact upon the financial attractiveness and adoption of GEVs. To assess the impact of potential monetary incentives, a scenario was created using a similar set of incentives to those that were adopted for commercial hybrids. For segment 5, a $20,000 tax credit was applied to EV and PHEV-40. As shown in Figure 3DD, the impact of these incentives was to make PHEV-40 cost competitive with ICE and HEV by 2012 and to make EV the lowest cost option by approximately 2015.

Vehicle Specifications

<table>
<thead>
<tr>
<th>ICE</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Drivetrain</td>
<td>6.7L Diesel / Auto</td>
<td>6.7L Diesel / Auto</td>
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<td>Fuel System Cost</td>
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<td>Exhaust Gas Efficiency Improvements (10% of MPG increase)</td>
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<td>$46</td>
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<tr>
<td>Fuel Economy</td>
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<td>15 MPG</td>
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</table>

<table>
<thead>
<tr>
<th>PHEV-40</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Range</td>
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<td>Battery Size</td>
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<tr>
<td>Inverter Cost</td>
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</tr>
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<td>On-Board Charger Cost</td>
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<table>
<thead>
<tr>
<th>HEV</th>
<th>2010</th>
<th>2020</th>
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</thead>
<tbody>
<tr>
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<table>
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<td>Inverter Cost</td>
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<td>$3,375</td>
</tr>
<tr>
<td>Charger Size</td>
<td>10 kW</td>
<td>10 kW</td>
</tr>
</tbody>
</table>

Source: PRTM Analysis
Fleet Adoption of GEVs in 2015

While competitiveness timeframes vary by drivetrain configuration and industry segment, fleet customers in aggregate could contribute substantial sales volumes to the early GEV industry, helping to achieve economies of scale and drive down costs for the broader consumer market.

Total cost of ownership is likely to play the greatest role in determining electric drive application in fleets. However, an additional critical factor is the difficulty that the operator faces in switching to new technology. Fleet operator switching difficulty will be of particular importance for EVs. For segments such as taxis, the operating difficulty will be great enough that it will become a significant deterrent to selecting EVs, despite a potential cost of ownership advantage. The key factors that will influence switching difficulty are driving range margin, infrastructure deployment and charging. Combining these criteria, switching difficulty can be broadly categorized by three levels:

- **Low**: Minimal Impact to Fleet Operations (No range issues, minimal infrastructure complexity)
- **Med**: Operating Changes Likely But Containable
- **High**: Significant Differences to Current Operating Practices (e.g. taxi range limitations)

Combining switching difficulty and the relative TCO, a perspective can be gained on the attractiveness of GEVs for the different segments at a given point in time. Based on this, an assessment of the likely relative adoption rates can be made for the different segments. The segments with the lowest switching difficulty and the highest TCO benefit will be the segments most likely to have the highest adoption rate. Conversely, the segments with the highest switching difficulty and the lowest TCO benefit will have the lowest adoption rate.

Applying this framework to the base case, by 2015, it is likely that a much larger portion of fleet operators will begin to transition their fleets to GEVs. In this scenario, fleet operators could begin to transition their fleets as early as 2011 and by 2015, as much as 6 to 7 percent of the targeted fleet segment sales could be plug-in vehicles. This would drive annual sales of approximately 130,000 units in 2015 and would result in a 2015 parc of more than 200,000 GEVs.
By implementing a relatively modest set of policies, Congress has an opportunity to address our most urgent challenges and spur sustainable growth.
ABSTRACT

Targeted public policies could help to facilitate the adoption of grid-enabled vehicles by commercial and government fleet operators. Temporary point-of-sale purchase incentives can offset the higher upfront cost of electric drive vehicles and charging infrastructure. By making vehicle and infrastructure tax credits transferable, the private sector as well as federal, state and local public sector entities would benefit from reduced costs. Finally, the federal government can provide valuable risk mitigation during the early development of the battery industry by offering targeted support for the used battery market.

The policy recommendations identified in this section are intended to support the early adoption of electric drive vehicles in managed fleets. They are not, however, intended as a substitute for policies promoted by the original Electrification Roadmap. Rather, commercial and government fleets can be viewed as extensions of the deployment community concept in which an efficiently designed network of private and public charging infrastructure along with utility integration could enable significant penetration of grid-enabled vehicles.

CHAPTER 4.1

Fleet Microsystems

Electric drive vehicles should be an attractive investment for a number of commercial and government fleets in the near term. However, public policy can help to reduce risk, provide more business certainty, and ultimately increase adoption sooner, benefiting the broader market.

In many cases, fleets function as a microcosm of a transportation ecosystem that could manage many—if not all—of the key elements of an electrification ecosystem or deployment community. For example, a fleet might consist of numerous vehicles that a business operates in a confined geographical space. This is certainly true for mid-sized fleets that operate as part of geographically constrained businesses such as utilities or city government fleets. For national fleets, such as parcel delivery and telecommunications fleets, this is true for at least a subset of their vehicles that serve individual regions or urban areas. Because of their unique characteristics, operators of fleet vehicles might be able to more easily overcome the challenges that other drivers would face in adopting GEVs. For instance, centrally refueled fleets provide refueling systems for their vehicles at a home base or bases, making it easier and more cost-effective to charge fleet GEVs.

The various types of financial support that would be available to consumers and infrastructure providers in deployment communities should be available to fleet operators, who may serve as a kind of electrification micro-ecosystem—or fleet microsystem. Like electrification ecosystems, GEV fleet microsystems offer the opportunity to accelerate the adoption of grid-enabled vehicles by promoting the scale and cost reductions in battery and vehicle production that will accompany them. While fleets represent a smaller market than the general personal use auto market, the obstacles to their adoption of electric drive technology are smaller in some cases and can be addressed by the policy recommendations that follow. It is of particular importance to appreciate that in promoting fleet GEVs now, we can accelerate the adoption of GEVs in the general personal-use auto market.

POLICY RECOMMENDATION

Expand the tax credits for light-duty grid-enabled vehicles purchased in deployment communities to include private sector fleets.

Light-duty vehicles (cars and class 1 and 2 trucks) comprised 55 percent of all U.S. fleet vehicles in operation in 2009. They therefore represent a substantial opportunity to deploy grid-enabled vehicles, achieve scale in the battery industry, and reduce costs for all consumers. As explained above, deployment of these vehicles into the broader consumer market faces several challenges which may be more easily overcome in the fleet market. However, the higher upfront costs and long payback periods remain a critical issue to address in promoting light-duty vehicles in fleets.

To support the deployment of GEVs in fleets, the temporary tax credits that Congress establishes for grid-enabled vehicles purchased in deployment communities (assuming pending legislation passes) should be made available to fleet operators nationwide who purchase more than 10 GEVs per year. The credits should also be extended to fleets that include more than 25 total GEVs that are centrally fueled or whose drivers have access to home and/or workplace charging equipment. (In the event that the federal tax credit available to purchasers of grid-enabled vehicles in deployment communities remains the same as the federal tax credit available throughout the nation, then the base federal tax credit for fleet GEVs should be increased by $2,500 per vehicle.)
Public Policy and the Tax Code

The Electrification Coalition is proposing a broad range of policies to promote the deployment of HEVs, PHEVs and EVs into fleets. Several of those policies involve the creation of tax credits. Lawmakers’ use of the tax code to promote policy outcomes is not without controversy. Most pointedly, several observers have suggested that such policies would be more appropriately designed as grants or other programs subject to appropriations. However, while it may have been more practical to implement programs similar to those proposed by the Electrification Coalition through appropriated funds, that may not currently be the case. Clearly, Congress and the president have the ability to change the law at any time. Yet, provisions in the tax code are generally regarded as more certain than other types of government incentives. That certainty facilitates adoption of the actions that the policies are intended to promote. Stated differently, tax credits are more likely to achieve their stated goal than programs supported by appropriated funds, the availability of which often fluctuates from year to year. Accordingly, the tax code has been used to support the energy industry in particular for decades. Tax incentives have long been available to the oil and gas industry, the renewable power industry, the appliance industry, and the automotive industry. In short, because businesses making long term investments are often unwilling to make them in the absence of financial certainty, it has become common practice to use the tax code to support the nation’s energy policy priorities. Use of the tax code also offers a transparent opportunity to ensure that tax expenditures in support of different vehicle technologies are established based on a neutral metric.

Finally, there is a clear and well developed means to deliver incentives offered through the tax code to their intended beneficiaries. New programs by appropriated funds often require the development of a new infrastructure to distribute the available funds. That process can be expensive, take substantial time, and still not achieve intended results. The Department of Energy’s loan guarantee program, for instance, is a well documented example of a program established to assist an industry that took years to get off of the ground and failed to deliver the benefits Congress made available to the intended beneficiaries.

Policy Recommendation

Create tax credits for medium- and heavy-duty grid-enabled vehicles deployed in fleets with greater than 10 vehicles in operation.

As of October 2010, no credit exists for the purchase of a medium- or heavy-duty plug-in electric vehicle weighing more than 14,000 lbs. Current federal tax credits for the purchase of hybrid electric vehicles apply to light-duty vehicles placed into service after December 31, 2005.1 Consumers purchasing a light-duty HEV through December 31, 2010, are eligible for a federal income tax credit of up to $3,400.2 Credit amounts begin to phase out for a given manufacturer once it has sold more than 60,000 eligible vehicles, and the credit is scheduled to expire after 2010.3 Some states offer additional incentives to supplement the federal tax credits.

More recently, federal credits for the purchase of a qualified plug-in vehicle (EV or PHEV) have been introduced for consumers nationwide with a 200,000 vehicle per-manufacturer cap.4 The maximum federal credit available is $7,500, and state credits range as high as $8,000 per vehicle.5 This focus on supporting the development of technologies and products that meet the needs of mainstream American consumers is clearly essential. Policymakers have rightly targeted incentives to match the vehicle segment that can ultimately make the most significant progress toward meeting their goals: increased energy security, reduced CO2 emissions in the transportation sector, and a scalable industry that benefits the American economy and American workers. However, volume production of advanced battery cells will generate cost savings regardless of whether the final pack configuration is geared for light-, medium-, or heavy-duty vehicles.

Part Three of this Roadmap identified a number of applications in which heavier IV and PHEV trucks represent an attractive option for commercial and government fleet operators. These trucks could sharply reduce vehicle petroleum consumption as well as tailpipe emissions of particulate matter compared to their ICE counterparts. Moreover, the benefit they provide to the nation may be even greater. By drawing power from the electrical grid, PHEVs and EVs further reduce the nation’s oil consumption while improving the transportation sector’s CO2 profile. At the same time, to the extent that such vehicles require larger batteries to operate, they will further assist the battery industry in increasing scale in cell manufacturing, bringing costs down for batteries for all vehicles.

To accelerate the cost-effective integration of medium- and heavy-duty GEVs in commercial and government fleets, Congress should create a tax credit of up to $15,000 for fleet operators who purchase a qualifying grid-enabled class 3 truck. The maximum credit should be increased to $20,000 for grid-enabled class 4-5 trucks and $25,000 for grid-enabled class 6-7 trucks. After 2015, the maximum credit value will no longer be necessary. Therefore, to promote fiscal responsibility, the maximum credit should be available through 2015. Congress should ensure the tax credit value of the credits should decline in a linear fashion each year before reaching zero in 2020.

Policy Recommendation

Create clean renewable energy bonds for fleet vehicle charging infrastructure, and make municipal and regional transit authorities eligible for the bonds.

Clean renewable energy bonds (CREBs) are bonds in which interest on the bonds is paid in the form of federal tax credits by the United States government in lieu of interest paid by the issuer. CREBs effectively allow the borrower to access funds for qualifying projects without incurring any interest expense. The tax credit that is assigned to the holder of a CREB can be used to offset, on a dollar for dollar basis, its own tax liability. The value of the tax credit is then treated as taxable income to the bondholder.

Congress created CREBs in the Energy Tax Incentives Act of 2005. Eligible bond issuers include state and local governments and electric cooperatives that are undertaking projects that generate clean power. The American Recovery and Reinvestment Act expanded the original CREB program. The law authorized an additional $2.4 billion of qualified energy conservation bonds and clarified that capital expenditures to implement green community programs includes grants, loans and other repayment mechanisms to implement such programs. Implementation of CREBs to the states to issue CREBs to finance retrofits of existing private buildings through loans and/or grants to individual homeowners or businesses, or through other repayment mechanisms.

The eligible uses of CREBs should be expanded to support assistance provided by state or local governments for vehicle charging infrastructure for fleet operators that purchase or have purchased at least 10 centrally-charged grid-enabled vehicles in one year or operate at least 25 centrally-charged grid-enabled vehicles. This would provide state and local governments with an opportunity to attract GEV fleets to their communities as well as support their development. In urban areas with high levels of tailpipe particulate emissions, CREBs for fleet infrastructure might also represent a cost-effective tool for reducing air pollution. The expanded uses of CREBs should include the purchase and installation of charging infrastructure only, not the creation of competitive energy companies.

1 DOE, Paul Revere grant, Federal Tax Credits for Hybrids, available online at http://www.howto-energy.org/sgx/tea/hybrid.html
2 Id.
3 Id.
4 DOE, EERE, Alternative Fuels and Advanced Vehicles Data Center, available online at http://www.afdc.energy.gov/afdc/bis/ems/CA/8616
5 Id.
6 ARRA, Section 1349
7 DOE, EERE, Alternative Fuels and Advanced Vehicles Data Center, available online at http://www.afdc.energy.gov/afdc/bis/ems/CA/8616
Policy Recommendation

Extend the existing tax credit for electric vehicle charging infrastructure through 2018 and expand the range of eligible costs to include upgrades performed by a utility to support fleet electrification and to facility owners for electrical power distribution equipment upgrades necessary to operate and monitor charging infrastructure.

In some situations, utilities may have to upgrade equipment in order to reliably serve large numbers of GEVs charging at fleet depots. Typical improvements would consist of upgraded transformers and—in some circumstances—radial distribution lines (the lines that exclusively connect the utility customer to the grid). In the context of serving residential neighborhoods where personal use vehicles would generally be charged overnight, utilities would generally absorb the cost of transformer upgrades and recover those costs over time in their rate base. Where the upgrades are to commercial facilities, however, and serve predominantly or exclusively a single customer, many utilities will charge the cost of such upgrades directly to the customer. Moreover, commercial facility owners may need to invest in upgrades to electrical power infrastructure not owned by the utility. The expense related to components such as controls, panel boards, switches, transformers and safety switches, power management equipment, and software should be eligible for the credit.

Existing law offers commercial customers a tax credit of 50 percent up to $50,000 for the installation of charging equipment that enters into service before the end of 2010. Congress should extend the existing tax credit for the installation of charging infrastructure through 2018. Moreover, Congress should expand the range of eligible costs for operators of fleets that purchase or have purchased at least 10 centrally-charged grid-enabled vehicles in one year or operate at least 25 centrally-charged grid-enabled vehicles.

Immediate expensing (or accelerated depreciation) benefits companies by allowing them to retain the time-value-of-money of their near-term tax obligations and defer payment of taxes until later years when those cash flows are less valuable on a discounted basis. Thought of differently, the government effectively loans the company their tax liability for a few years. This policy possesses the unique fiscal benefit of capitalizing on the arbitrage between a company’s cost of capital (typically 10-25 percent) and the federal government’s cost of capital (approximately 5 percent).

This financial accounting dynamic increases the efficiency of the policy as the component’s benefit outweighs the government’s direct cost. For instance, an item purchased by a company for $1,000 dollars today has a tax-adjusted net present cost of $860 if the asset is entirely expensed in year one. If the item is depreciated over 10 years, however, the item’s purchase represents a tax-adjusted net present cost of $785, a $105 premium over the immediate expensing scenario. From the government’s perspective, however, immediate expensing appears to cost $833 in lost tax revenues and the 10-year depreciation scenario costs $270, a $63 difference. In effect, the business receives a $105 subsidy whereas the government incurs a $63 cost. For the purposes of budget scoring, however, the Joint Tax Office does not typically discount future tax receipts, so this dynamic is further enhanced; immediate expensing should score at close to a zero cost to the government.

Policy Recommendation

Make tax credits for the purchase of qualifying grid-enabled vehicles and related charging infrastructure transferable.

As in the original Electrification Roadmap, a number of the policies recommended here involve changes to the tax code, including credits. A tax credit is a sum that a taxing entity is allowed to deduct from the amount of taxes it owes the government. Unlike tax deductions, which generally reduce only taxable income, tax credits reduce a taxpayer’s tax liability dollar for dollar. Stated differently, so long as a taxpayer has tax liability, a one dollar tax credit should be worth one dollar to a taxpayer.

In the electric vehicle market, however, a large number of market participants do not have tax liability that a tax credit can offset. Some market participants are state or local governments or non-profits that are purchasing EVs and PHEVs or installing charging infrastructure. Other market participants are start-up companies that are not yet profitable or individuals who do not have sufficient tax liability to take advantage of the credits related to the purchase of vehicles or the installation of charging infrastructure.

To mitigate this situation, the tax credits available for the purchase of qualifying grid-enabled vehicles and related charging infrastructure should be transferable. Making credits transferable would allow the owner of a credit who does not have sufficient tax liability to monetize it by reducing its tax payments to instead monetize it by selling it to other taxpayers who have tax liability. While making the tax credits transferable introduces some complexity to the system and likely will generate some opposition from those who are generally against the use of the tax code to support electric drive vehicles, it is the best way to ensure that the tax credits can have their intended effect. If Congress passes tax credits that cannot be used by the intended recipients, it is likely that the tax credits will not have their intended effect.

Policy Recommendation

Incentivize the establishment of special purpose entities to facilitate bulk purchasing of electric drive vehicles by fleet operators.

In many instances, fleet operators might have an opportunity to adopt special purpose PHEVs and EVs, such as delivery trucks or utility bucket trucks, but are unable to find a manufacturer who can produce a small number of vehicles at a reasonable price. At the same time, individual OEMs may be hesitant to commit to producing substantial volumes of larger EVs and PHEVs, because the customer base is highly fragmented and uncertain.

However, the chassis and drivetrains used by multiple special purpose vehicles are often practically identical—only the vehicle exterior differs to any significant degree. In these cases, customers could potentially benefit from aggregating bulk purchase orders for special purpose EV and PHEV drivetrains. Individual OEMs would also benefit from the certainty associated with larger orders. To promote bulk purchasing orders that otherwise might not be viable, Congress should incentivise the establishment of special purpose entities to aggregate GEV orders from disparate purchasers.

Vehicle purchased through such entities would be eligible for enhanced tax credits based on the size of the bulk order. The tax credits would be a function of, and in addition to, any other tax credit available to GEVs. For orders of at least 100 vehicles, the additional tax credit would be equal to 20 percent of the value of the baseline GEV tax credit applicable to that vehicle. For orders of at least 500 vehicles, the additional tax credit would be equal to 30 percent, and for orders of at least 1,000 vehicles, the additional tax credit would be equal to 40 percent of the value of the baseline GEV tax credit applicable to those vehicles.

6 Assumes a 10% cost of capital for business, a 5% cost of capital for government and a 35% corporate tax rate.
CHAPTER 4.2

Other Policies

Fleet microsystems represent an important opportunity to accelerate adoption of GEVs among commercial and government fleet operators. Additional policies beneficial to the broader market could help to reduce the risk of battery purchases and help accelerate technological development.

Reinstate and extend the tax credit for medium- and heavy-duty gasoline hybrid electric vehicles that utilize advanced batteries with energy and power density equal to or greater than lithium-ion batteries.

Increased deployment of HEVs represents an opportunity for increases in scale that can reduce costs for all large-format automotive-grade batteries. In 2005, Congress established a tax credit for the purchase of medium- and heavy-duty hybrid electric vehicles. The tax credit was worth between 20 and 40 percent of the incremental cost of a hybrid vehicle subject to limits based on the vehicle’s efficiency. The tax credit expired, however, at the end of 2009. In 2010, legislation was introduced that would extend and expand the tax credit, but it did not pass. The EC believes that medium- and heavy-duty hybrid vehicles, many of which serve in fleets, can substantially promote the deployment of all GEVs by adding scale to battery production, thereby reducing battery costs for all vehicles. Therefore, the tax credit that expired at the end of 2009 should be extended and expanded generally consistent with the provisions of S. 2854, introduced by Senators Herb Kohl (D-WI) and Orrin Hatch (R-UT), which would extend it through the end of 2014 and expand the size of the tax credit available to medium- and heavy-duty hybrid trucks subject to the limits stated in the table below. Consistent with its purpose of promoting scale production of batteries for use in all vehicles, availability of the credit should be limited to vehicles that utilize advanced batteries with energy and power density equal to or greater than lithium-ion batteries.

<table>
<thead>
<tr>
<th>VEHICLE WEIGHT</th>
<th>MAX FOR 20% FE INCREASE</th>
<th>MAX FOR 40% FE INCREASE</th>
<th>MAX FOR 50% FE INCREASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,500-14,000 lbs</td>
<td>$1,500</td>
<td>$2,500</td>
<td>$3,000</td>
</tr>
<tr>
<td>26,001–33,000 lbs</td>
<td>$3,000</td>
<td>$4,500</td>
<td>$6,000</td>
</tr>
<tr>
<td>&gt;33,000 lbs</td>
<td>$4,000</td>
<td>$6,000</td>
<td>$8,000</td>
</tr>
</tbody>
</table>

**Policy Recommendation**

Establish a program to guarantee the residual value of the first generation of large-format automotive batteries put into service between 2010 and 2013.

The battery frequently is the most expensive component in a PHV or EV. Even when a battery is no longer capable of storing a sufficient charge to support the operation of a vehicle with adequate power and range, it likely will still have ample life to serve in other capacities where energy density and weight are not as important as in vehicles, such as furnishing up intermittent power, serving as a source of emergency backup power, or as a source of distributed generation. Therefore, a “used” vehicle battery will still have value that the consumer can capture at the time of vehicle or battery disposal, and which can serve as an additional incentive at the time of purchase. There is, however, a sequencing problem that makes it difficult to understand the value of the “used” battery, and which makes it likely to undervalue its value: a market for secondary uses of automotive-grade batteries cannot develop until there are used batteries, but those damaged in accidents.

**Policy Recommendation**

The Department of Energy should establish a program to guarantee the minimum residual value of their battery for a defined period of time after the purchase of the vehicle that shall include the following provisions:

1. The guarantee applies only to a battery purchased in a new vehicle, and the battery must remain in the vehicle until the sale that triggers the guarantee, but is transferable to subsequent owners of the vehicle.
2. The guarantee equals $50 per kWh of nameplate capacity for a period of one year after the expiration of its warranty. The guarantee declines by 50 percent until the end of the second year after the expiration of its warranty, after which it is no longer available.
3. For the guarantee to be available, the battery must have been covered by a warranty for at least two years and must be intact, but need not be working. In other words, the guarantee will not pay for damaged batteries, such as those damaged in accidents.
4. The guarantee will be available to certified purchasers of batteries. If the value of the battery is less than the guaranteed minimum residual value, the Department of Energy will pay certified battery purchasers the difference between the guaranteed residual value and the market price of the battery. That will allow the certified purchaser to purchase the battery from a vehicle/battery owner at the guaranteed minimum residual value.
5. Any entity may seek certification by the Department of Energy as a participant in the program.
Under this program, owners of vehicles with qualifying batteries will be able to sell a battery to a certified entity for a guaranteed minimum price. The entity will pay the price because the government will pay it, the difference between the minimum price and the market price. The certified entity will be responsible for demonstrating the amount of the guarantee. In other words, it will need to demonstrate the market price in order to be able to obtain the guarantee. This requirement is necessary to ensure that the guarantee is only paying for the difference between a real market price and the guarantee.

In the absence of a party responsible for ensuring the integrity of the transactions, parties could try to sell batteries at below market prices solely to get the value of the guarantee. This requirement is necessary to prevent this from happening.

Policy Recommendation

Increase federal investment in advanced battery research and development.

The high cost of automotive-grade batteries is widely considered to be the most significant obstacle to more rapid GEV adoption. While it is anticipated that large-scale manufacturing and learning will help bring these costs down in the future, additional investment in battery research and development (R&D) remains crucial. Continued technological breakthroughs will help improve battery durability and reliability, ensure battery safety, and extend battery life spans. Battery makers also point to innovation as potentially more important than scale in delivering sustainable cost reductions.

Battery development will improve the potential for technological crossover as storage for wind and solar power generation and other secondary use applications.

Commercial vehicles are regulated as trucks when gross vehicle weight (GVW) exceeds 10,000 lbs. This distinction has important implications from a regulatory standpoint. Automobiles and class 1 and 2 truck emissions are measured by the composite of the tailpipe emissions. However, vehicles in excess of 10,000 GVW are covered by the Environmental Protection Agency’s (EPA) regulations and are therefore subject to additional requirements on agencies.

Policy Recommendation

Ensure that federal motor vehicle regulations do not unnecessarily prohibit the development and deployment of cost-effective PHEVs in large trucks.

As the largest consumer in the nation, with a presence that extends throughout the economy, the federal government is well situated to help establish the market for GEVs. Executive Order No. 13423, issued by President Bush in 2007, directed agencies with 20 or more vehicles to purchase PHEVs when commercially available at a cost comparable to non-PHEVs. Executive Order No. 13514, issued by President Obama, imposes additional requirements on agencies to reduce greenhouse gas emissions from the federal fleet by 2 percent annually until 2020 and extends the requirement to E.O. 13423 to reduce fuel consumption by 2 percent annually through 2020 as well.

Currently, the downsized engines used in typical PHEV configurations would need to meet the same standards as a traditional engine. Meeting this standard is both cost-prohibitive and unnecessary. Downsized PHV engines are not designed to serve as a stand-alone source of motive power, and the cost and inefficiency associated with such a design has driven industry to avoid this approach. Instead, current medium- and heavy-duty hybrid vehicles in the market utilize a full-sized diesel engine in conjunction with a battery and motor, a configuration that erodes the cost savings-potential of the PHV design.

The regulatory requirements for engine testing should be modified to enable the use of smaller engines in medium- and heavy-duty PHEVs. The benefits would be substantial for vehicle cost and ultimately for fuel savings given the overall fuel intensity of medium- and heavy-duty trucks today. As the modeling analysis in Part Three of this Roadmap shows, PHEVs will become an economically viable alternative to ICE vehicles in a number of truck applications over the medium term. If left unaddressed, however, regulatory statutes will effectively restrict adoption.

Policy Recommendation

Encourage federal government adoption of electric drive vehicles.

FIGURE 4C

U.S. DOE Spending on Energy Research and Development

to an accelerated pace of technological advancement in battery production, driving down costs. Large fleet purchases will also give automotive and battery OEMs the long-term stability needed to justify significant investments in labor and equipment.

Despite the existence of executive orders that direct agencies to purchase efficient and advanced vehicles, agencies often choose to meet the requirements in the least expensive manner. Rather than forcing agencies to pay the incremental costs of GEVs out of their own budgets, Congress should establish a program at the General Services Administration that will pay the incremental costs of GEVs purchased or leased by federal agencies. Directly appropriating funds for that purpose would allow agencies to operate GEVs without taking scarce funds away from their core missions. Moreover, introducing this program and transparency to the adoption of GEVs by federal agencies will allow Congress and the public to better calibrate the rate at which GEVs are incorporated into the federal fleet.

**Post Office**

As of 2009, the United States Postal Service (USPS) had nearly 220,000 vehicles in operation. The vast majority of the vehicles—nearly 195,000—were light trucks. According to a 2009 report by the USPS Office of the Inspector General, the average daily mail-delivery driving distance is 18 miles, making many of these vehicles well-suited for right-sized EV batteries or smaller PHEV batteries. Moreover, the average age and usage patterns of vehicles currently in the postal fleet lead to extremely high maintenance costs. Substituting EVs and PHEVs would result in sharply lower fuel costs in addition to offsetting high maintenance costs.

The key issue for the USPS has been funding the upfront investment needed to acquire EVs and PHEVs. As a semi-private institution, the post-office has limited access to capital and may actually face additional, unique funding challenges. In 2009, the USPS faced a $7 billion funding shortfall. Of course, reducing fuel and maintenance costs could contribute to a stronger position over time, but access to capital today is still a key issue.

From an economic standpoint, the IG report found that value was achievable in the right circumstances. Specifically, the report found that if “the upfront capital cost is overcome by participation in DOE-funded demonstration programs and V2G revenue is captured, the agency [breaks] even within the first 2 years that EVs are in operation.” The report goes on to state that “Funding specifically targeting Postal Service mail delivery vehicles would likely be necessary to create an economic environment that provides incentives for the Postal Service to move into a leadership position with EV technology.”

Given the size and purchasing power of the USPS, the federal government should offset the incremental upfront cost of EV and PHEV purchases by the Post Office for the period 2011-2014 through direct appropriations to the USPS. At the end of this four-year period, the Inspector General should be required to produce an analysis of the program and make recommendations on the need for a possible second phase.

**Policy Recommendation**

Clarify the tax code to ensure that Section 30D GEV tax credits are available to consumers who purchase a GEV (without a battery) and lease the battery from the dealer or a third party at the time the vehicle is purchased.
CONCLUSION

Oil dependence ranks among the most pressing national and economic security threats confronting the United States today. The importance of oil to the U.S. economy has necessitated an assertive foreign policy that emphasizes security of supply in regions of the world rife with violence and instability. The decline of conventional domestic petroleum reserves has resulted in increased U.S. oil imports, expanding the trade deficit and hastening the export of American wealth abroad. More importantly, the fundamental dynamics driving oil price volatility in recent years are not expected to significantly alter over the long term. Rapidly expanding oil demand in emerging markets, constrained growth in low-cost oil supplies, and thin spare capacity margins will continue to make the market prone to price shocks in the years to come. Recent history has repeatedly demonstrated that oil price shocks frequently result in recession, public debt expansion, and high unemployment for the United States.
## Top 50 Commercial Fleets

<table>
<thead>
<tr>
<th>RANK/COMPANY</th>
<th>CONTACT</th>
<th>OWNED</th>
<th>LEASED/MANAGED</th>
<th>CARS</th>
<th>CLASS 1-2</th>
<th>CLASS 3-8</th>
<th>VANS</th>
<th>SUVS</th>
<th>XUV</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ARK</td>
<td>St. Louis, MO</td>
<td>Joanne Webber</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>27,429</td>
</tr>
<tr>
<td>2</td>
<td>United Parcel Service (UPS)</td>
<td>Atlanta, GA</td>
<td>Mike Hance</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20,724</td>
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<tr>
<td>3</td>
<td>Veracare</td>
<td>Philadelphia, PA</td>
<td>Joe O'Driscoll</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15,518</td>
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<tr>
<td>4</td>
<td>Capital Corp.</td>
<td>Philadelphia, PA</td>
<td>Bud Maddock</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12,489</td>
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<tr>
<td>5</td>
<td>Federal Express Corp.</td>
<td>Memphis, TN</td>
<td>Russell Morgan</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8,651</td>
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<tr>
<td>6</td>
<td>Pfitz, Inc.</td>
<td>New York, NY</td>
<td>Fred Sauer</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8,000</td>
</tr>
<tr>
<td>7</td>
<td>Coca-Cola Enterprises (H)</td>
<td>Atlanta, GA</td>
<td>John Kay Rustum</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7,825</td>
</tr>
<tr>
<td>8</td>
<td>Proven Communications</td>
<td>skyline, AZ</td>
<td>Roger Knovisky</td>
<td>90%</td>
<td>Bank of America 5%, GE Fleet 5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7,171</td>
</tr>
<tr>
<td>9</td>
<td>Poynter, Inc.</td>
<td>Kansas City, KS</td>
<td>Potea Silva</td>
<td>97%</td>
<td>GE Fleet 50%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,293</td>
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<tr>
<td>10</td>
<td>ServiceMaster</td>
<td>Monterey, CA</td>
<td>Steve Glichon</td>
<td>37%</td>
<td>PHH 25%, PHH 2%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,165</td>
</tr>
<tr>
<td>11</td>
<td>Tyson International</td>
<td>Greensboro, NC</td>
<td>Kevin Bowersox</td>
<td>50%</td>
<td>GE Fleet 50%, Wheels 50%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4,231</td>
</tr>
<tr>
<td>12</td>
<td>Savme Shared Services, LLC</td>
<td>Reno, NV</td>
<td>Jim McCarthy</td>
<td>1%</td>
<td>Wheels 97%, AR 2%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,122</td>
</tr>
<tr>
<td>13</td>
<td>Salvation Army</td>
<td>Alabaster, AL</td>
<td>Bob Jones</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,300</td>
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<tr>
<td>14</td>
<td>State Farm Mutual Auto Insurance Co.</td>
<td>Bloomfield, CT</td>
<td>Malcolm Tiff</td>
<td>94%</td>
<td>Chrysler Financial 7%, GE Fleet 2%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,192</td>
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<tr>
<td>15</td>
<td>Midland Materials Group</td>
<td>Atlanta, GA</td>
<td>Ron Puckett</td>
<td>89%</td>
<td>PHH GE Fleet, Donlin</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4,684</td>
</tr>
<tr>
<td>16</td>
<td>Cox Enterprises</td>
<td>Atlanta, GA</td>
<td>Mark Launberger</td>
<td>-</td>
<td>GE Fleet, Wheels</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,859</td>
</tr>
<tr>
<td>17</td>
<td>Sears Holding Corp.</td>
<td>Hoffman Estates, IL</td>
<td>Tiffany Matthews</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,748</td>
</tr>
<tr>
<td>18</td>
<td>Dauncey Services</td>
<td>Houston, TX</td>
<td>Butch Christian</td>
<td>85%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,727</td>
</tr>
<tr>
<td>19</td>
<td>Mears Corp.</td>
<td>Rochester, MN</td>
<td>Pat Hjort</td>
<td>-</td>
<td>GE Fleet 100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,702</td>
</tr>
<tr>
<td>20</td>
<td>Merck &amp; Co., Inc.</td>
<td>Whitehouse Station, NJ</td>
<td>Scott Launder</td>
<td>97%</td>
<td>PHH 3%, Wheels 3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,914</td>
</tr>
<tr>
<td>21</td>
<td>United Technologies Corp. (UTC)</td>
<td>Huntsville, AL</td>
<td>Patrick McSween</td>
<td>95%</td>
<td>PHH 25%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,875</td>
</tr>
<tr>
<td>22</td>
<td>Saville-Howell</td>
<td>Brick, NJ</td>
<td>Steve Moore</td>
<td>-</td>
<td>GE, PHH, PHH</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,963</td>
</tr>
<tr>
<td>23</td>
<td>Tidepoint</td>
<td>New York, NY</td>
<td>Shirley Collins</td>
<td>-</td>
<td>PHH 60%, AR 40%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,418</td>
</tr>
<tr>
<td>24</td>
<td>Sendex Parks Company</td>
<td>Jersey City, NJ</td>
<td>Chris Liang</td>
<td>50%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,030</td>
</tr>
<tr>
<td>25</td>
<td>Champion</td>
<td>Going, NC</td>
<td>Karl Travis</td>
<td>83%</td>
<td>AR GE Fleet</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,095</td>
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<tr>
<td>26</td>
<td>Aramark Services, Inc.</td>
<td>Philadelphia, PA</td>
<td>Kevin Fisher</td>
<td>30%</td>
<td>GE Fleet 40%, PHH 20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,579</td>
</tr>
<tr>
<td>27</td>
<td>Otsi Alexander</td>
<td>Bensalem, PA</td>
<td>Phil Schreiber</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,038</td>
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</table>

Source: Fleet Management - 2010 Automotive Fleet Factbook
## Available Vehicle Matrix – Passenger Portfolio

<table>
<thead>
<tr>
<th>MAKE</th>
<th>MODEL</th>
<th>TYPE</th>
<th>DESCRIPTION/CLASS (IF APPLICABLE)</th>
<th>BATTERY CAPACITY</th>
<th>ELECTRIC MOTOR CAPACITY</th>
<th>ELECTRIC DRIVING RANGE</th>
<th>TOP SPEED</th>
<th>PRICE</th>
<th>TARGET INTRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audi</td>
<td>e-tron</td>
<td>EV</td>
<td>2-door sports car based on the R8</td>
<td>42.4 kWh</td>
<td>230kW</td>
<td>8.4 hr</td>
<td>124 mph</td>
<td>-</td>
<td>2012</td>
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<tr>
<td>BMW</td>
<td>i8</td>
<td>EV</td>
<td>4-seat sedan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BYD Auto</td>
<td>e6</td>
<td>EV</td>
<td>4-door crossover</td>
<td>48kWh</td>
<td>75kW</td>
<td>91 mls</td>
<td>87 mph</td>
<td>-</td>
<td>2012</td>
</tr>
<tr>
<td>BYD Auto</td>
<td>e60</td>
<td>EV</td>
<td>4-door sedan</td>
<td>90-120 mls</td>
<td>105 mph</td>
<td>85 mph</td>
<td>45,000</td>
<td>-</td>
<td>2010</td>
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<tr>
<td>Chery Auto. Co.</td>
<td>S1R</td>
<td>EV</td>
<td>4-door compact</td>
<td>20kWh</td>
<td>90 mph</td>
<td>75 mph</td>
<td>32,000</td>
<td>Nov 2009 China</td>
<td></td>
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<tr>
<td>Citroën</td>
<td>C-ZERO</td>
<td>EV</td>
<td>4-door compact</td>
<td>30kWh</td>
<td>91 mph</td>
<td>85 mph</td>
<td>55,000</td>
<td>2010/2011 EU</td>
<td></td>
</tr>
<tr>
<td>Coda Automotive</td>
<td>CO34 Sedan</td>
<td>EV</td>
<td>4-door, mid-size sedan</td>
<td>36kWh</td>
<td>90 mph</td>
<td>95 mph</td>
<td>1,000</td>
<td>California test fleet mid 2010, public delivery Fall2010</td>
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<tr>
<td>Daewoo</td>
<td>Smart ED (Electric Drive)</td>
<td>EV</td>
<td>2-door micro car</td>
<td>10kWh</td>
<td>105 mph</td>
<td>90 mph</td>
<td>2012</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fiat</td>
<td>500e</td>
<td>EV</td>
<td>Small car</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Fiat</td>
<td>Nuova</td>
<td>PHEV</td>
<td>Family sedan</td>
<td>20kWh</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Ford</td>
<td>C-MAX</td>
<td>PHEV</td>
<td>MPV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>General Motors</td>
<td>e140</td>
<td>EV</td>
<td>4-door hatchback</td>
<td>36kWh</td>
<td>90 mph</td>
<td>100 mph</td>
<td>14,000</td>
<td>2011 US</td>
<td></td>
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<tr>
<td>General Motors</td>
<td>Opel Ampera</td>
<td>PHEV</td>
<td>4-door hatchback</td>
<td>40kWh</td>
<td>100 mph</td>
<td>100 mph</td>
<td>2011 USA</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Honda</td>
<td>EV N</td>
<td>EV</td>
<td>2-door, 4-seat micro car</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Honda</td>
<td>TID</td>
<td>PHEV</td>
<td>Midsize to large vehicle</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hyundai</td>
<td>Blue Ent</td>
<td>EV</td>
<td>4-door hatchback</td>
<td>35kWh</td>
<td>90 mph</td>
<td>87 mph</td>
<td>2012 China</td>
<td>-</td>
<td>Korea second half of 2010, 2012 Generally</td>
</tr>
<tr>
<td>Lightning Car Company</td>
<td>GT</td>
<td>EV</td>
<td>2-door coupe</td>
<td>-</td>
<td>120 mph</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2011-12 US</td>
</tr>
<tr>
<td>Lotus</td>
<td>Evora</td>
<td>EV</td>
<td>7 passenger minivan</td>
<td>-</td>
<td>100 mph</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Late 2010 Saxon</td>
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<td>Luminar</td>
<td>SE</td>
<td>EV</td>
<td>4-door compact</td>
<td>16kWh</td>
<td>47kW</td>
<td>112 mph</td>
<td>$10,000</td>
<td>-</td>
<td>-</td>
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<td>Mitsubishi</td>
<td>i-MiEV</td>
<td>EV</td>
<td>4-door hatchback / sub-compact</td>
<td>24kWh</td>
<td>80kW</td>
<td>90 miles</td>
<td>2010 EU</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Opel</td>
<td>Ampera</td>
<td>PHEV</td>
<td>4-door hatchback</td>
<td>40kWh</td>
<td>100 mph</td>
<td>100 mph</td>
<td>14,000</td>
<td>2011 EU</td>
<td></td>
</tr>
<tr>
<td>Peugeot</td>
<td>iOn</td>
<td>EV</td>
<td>4-door hatchback / compact</td>
<td>24kWh</td>
<td>80kW</td>
<td>90 miles</td>
<td>2012</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Renault</td>
<td>Fluence ZE</td>
<td>EV</td>
<td>4-door sedan</td>
<td>22kWh</td>
<td>75kW</td>
<td>90 miles</td>
<td>2011 EU</td>
<td>-</td>
<td>End of 2010</td>
</tr>
<tr>
<td>Renault</td>
<td>Zoe ZE</td>
<td>EV</td>
<td>Compact coupe</td>
<td>-</td>
<td>60kW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>REVA</td>
<td>N50</td>
<td>EV</td>
<td>Named for &quot;Multigeneration&quot; two-seater with a large roof</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>REVA</td>
<td>N80</td>
<td>EV</td>
<td>Named for &quot;Multigeneration&quot; two-seater with a large roof</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>SAIC</td>
<td>Roewe 550</td>
<td>PHEV</td>
<td>4-door sedan</td>
<td>16kWh</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2010 China</td>
</tr>
<tr>
<td>SAIC</td>
<td>Roewe 750</td>
<td>PHEV</td>
<td>4-door sedan</td>
<td>16kWh</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2010 China</td>
</tr>
<tr>
<td>Tazzari</td>
<td>Zero</td>
<td>EV</td>
<td>2-passenger</td>
<td>-</td>
<td>30kW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tesla</td>
<td>Roadster</td>
<td>EV</td>
<td>4-seat sedan</td>
<td>56 kWh</td>
<td>188 mph</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2008-2012 US</td>
</tr>
<tr>
<td>Tesla</td>
<td>Model S</td>
<td>EV</td>
<td>4-seat sedan, 7-pass seat</td>
<td>100 kWh (standard configuration)</td>
<td>215 mph</td>
<td>100 kWh, 210 kWh &amp; 300 miles (based on battery option)</td>
<td>57,480</td>
<td>2012 USA &amp; EU</td>
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<tr>
<td>Th!nk</td>
<td>City</td>
<td>PHEV</td>
<td>4-seat sedan, 2+2 seating</td>
<td>25kWh</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Toyota</td>
<td>Prius Plug-in</td>
<td>PHEV</td>
<td>4-door hatchback</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>Golf Blue-e-motion</td>
<td>EV</td>
<td>4-door hatchback</td>
<td>28.5 kWh</td>
<td>85kW</td>
<td>95 mls</td>
<td>80kW</td>
<td>45,000</td>
<td>2011</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>E-Up!</td>
<td>EV</td>
<td>2-door micro car</td>
<td>40kW</td>
<td>60 mph</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Wheego</td>
<td>LF1</td>
<td>EV</td>
<td>2-seat passenger mini car</td>
<td>30kWh</td>
<td>95kW</td>
<td>65 mph</td>
<td>33,995</td>
<td>2010/2010 US</td>
<td></td>
</tr>
</tbody>
</table>
# Available Vehicle Matrix – Commercial Portfolio

<table>
<thead>
<tr>
<th>MAKE</th>
<th>MODEL</th>
<th>TYPE</th>
<th>DESCRIPTION/CLASS (IF APPLICABLE)</th>
<th>BATTERY CAPACITY</th>
<th>ELECTRIC MOTOR CAPACITY</th>
<th>ELECTRIC DRIVING RANGE</th>
<th>TOP SPEED</th>
<th>PRICE</th>
<th>TARGET INTRO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder Electric Vehicles</td>
<td>Truck</td>
<td>EV</td>
<td>Class 3 Delivery Truck</td>
<td>80 kWh</td>
<td>80kW</td>
<td>0-60 mi</td>
<td>65 mph</td>
<td>-</td>
<td>02 2010 US</td>
</tr>
<tr>
<td>Boulder Electric Vehicles</td>
<td>Truck &amp; WUV</td>
<td>EV</td>
<td>Class 2 van</td>
<td>80 kWh</td>
<td>80kW</td>
<td>0-60 mi</td>
<td>70 mph</td>
<td>-</td>
<td>02 2010 US</td>
</tr>
<tr>
<td>Bright Automotive</td>
<td>IDEA</td>
<td>PMEV</td>
<td>Class 2 van</td>
<td>15kWh</td>
<td>n/a</td>
<td>n/a</td>
<td>60 mph</td>
<td>n/a</td>
<td>2013-14 US</td>
</tr>
<tr>
<td>DesignLine</td>
<td>EcoSmart I</td>
<td>EV</td>
<td>Bus (NEV Passenger)</td>
<td>260 kWh</td>
<td>240kW</td>
<td>0-60 mi</td>
<td>75 mph</td>
<td>$180K-700K</td>
<td>Available Now</td>
</tr>
<tr>
<td>Evi</td>
<td>Medium Duty (MD)Trucks &amp; Walker (WA) Vans</td>
<td>EV</td>
<td>Class 4, 5, 6 Trucks</td>
<td>99 kWh</td>
<td>Electric motor 95kW</td>
<td>Scalable up to 90 mi</td>
<td>70-80 mph</td>
<td>$100K-$150K</td>
<td>Available Now</td>
</tr>
<tr>
<td>Electrobuses</td>
<td>ZebNow</td>
<td>EV</td>
<td>Class 4 truck</td>
<td>60 kWh</td>
<td>55kW</td>
<td>Up to 70 mi</td>
<td>60 mph</td>
<td>$150K</td>
<td>Available Now</td>
</tr>
<tr>
<td>Ford</td>
<td>Transit Connect</td>
<td>EV</td>
<td>Class 1 Van</td>
<td>80 kWh</td>
<td>90kW</td>
<td>0-60 mi</td>
<td>75 mph</td>
<td>n/a</td>
<td>2010</td>
</tr>
<tr>
<td>IC Bus (Manitou)</td>
<td>CE Series</td>
<td>PMEV</td>
<td>School Route Bus &amp; Commercial Bus</td>
<td>25-50kWh</td>
<td>Li-ion, liquid-cooled battery pack</td>
<td>Charge-depleting range 40 mi</td>
<td>n/a</td>
<td>$100K</td>
<td>Available Now</td>
</tr>
<tr>
<td>Mercedes-Benz</td>
<td>Vito E-COLL</td>
<td>EV</td>
<td>Van</td>
<td>35kWh</td>
<td>70kW</td>
<td>0-60 mi</td>
<td>50 mph</td>
<td>-</td>
<td>2011</td>
</tr>
<tr>
<td>Medac</td>
<td>Bus Van</td>
<td>EV</td>
<td>Class 3 Truck / Van</td>
<td>52-65kWh</td>
<td>70kW</td>
<td>60-180 mi (depending on battery type)</td>
<td>50 mph</td>
<td>-</td>
<td>Available Now - Europe</td>
</tr>
<tr>
<td>Namcoar</td>
<td>eStar</td>
<td>EV</td>
<td>Class 3 Truck / Van</td>
<td>80 kWh</td>
<td>70kW</td>
<td>0-60 mi</td>
<td>50mph</td>
<td>$149,000</td>
<td>Available Now - US</td>
</tr>
<tr>
<td>Opelare</td>
<td>Side EV Bus</td>
<td>EV</td>
<td>Bus</td>
<td>80 kWh</td>
<td>75kW</td>
<td>0-60 mi</td>
<td>50 mph</td>
<td>-</td>
<td>Accepting orders</td>
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<tr>
<td>Proterra</td>
<td>EcoBus REBS</td>
<td>EV</td>
<td>Bus (50 passengers)</td>
<td>70 kWh</td>
<td>150kW</td>
<td>0-60 mi</td>
<td>65 mph</td>
<td>-</td>
<td>Available Now</td>
</tr>
<tr>
<td>Renault</td>
<td>Kangoo ZE</td>
<td>EV</td>
<td>Compact commercial van</td>
<td>22 kWh</td>
<td>44kW</td>
<td>0-60 mi</td>
<td>130 mph (81 mph) 20,000 euros (including battery)</td>
<td>20,000 euros (including battery) plus battery lease from 70 euros per month</td>
<td>Europe 2010</td>
</tr>
<tr>
<td>Sinowes</td>
<td>URBANUS Hybrid Bus</td>
<td>EV</td>
<td>Bus</td>
<td>-</td>
<td>-</td>
<td>3.5 mi</td>
<td>70 mph</td>
<td>-</td>
<td>Available Now</td>
</tr>
<tr>
<td>Smith Electric Vehicles</td>
<td>Edison</td>
<td>EV</td>
<td>Class 2 Van or Bus</td>
<td>40 kWh</td>
<td>90kW</td>
<td>0-60 mi</td>
<td>50 mph</td>
<td>-</td>
<td>Available Now</td>
</tr>
<tr>
<td>Smith Electric Vehicles</td>
<td>Newton</td>
<td>EV</td>
<td>Class 4-6 Truck</td>
<td>70 kWh</td>
<td>75kW</td>
<td>0-60 mi</td>
<td>50 mph</td>
<td>-</td>
<td>Available Now</td>
</tr>
</tbody>
</table>
Grid-enabled Vehicle (GEV)

Electric or hybrid-electric vehicles that can be plugged directly into the electric grid to recharge onboard batteries.

Extended-Range Electric Vehicle (EVSE)

Electric Vehicle Supply Equipment

Electric Mile

For an electric vehicle, an electric mile is any mile in which the vehicle is propelled by an electric motor.

Electric Vehicle (EV)

A vehicle propelled 100 percent by an electric motor, which forms part of an electric drivetrain. The power comes from a battery or from a combustion engine that powers a generator.

Advanced Metering

Adereced electrical metering enables measuring and recording of usage data at regular short intervals and provides this data to both consumers and energy companies.

Advanced Transmission

Electricity distribution that employs digital metering to improve provider communication and monitoring capabilities as well as permit the efficient management of power flows, especially from variable renewable sources.

Anytime

A measure of electrical output which represents a flow of one unit of electricity per second.

ARRA 2009


Battery-Electric Vehicle (BEV)

A type of electric vehicle (BEV) that is propelled by an electric motor and uses the chemical energy stored in on-board batteries to power the motor.

Blended Mode

In a hybrid electric vehicle, operating in blended mode uses both an electric motor and a gasoline engine operating simultaneously and in conjunction to power the vehicle's drivetrain.

Carbon-Dioxide Equivalents

The amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas.

Charge-Depleting (CD) Mode

EVs and PHEVs operating in charge-depleting mode are drawing motive power and energy from the battery and reducing its state of charge. EVs always operate in charge-depleting mode.

Charge-Sustaining Mode

PHEVs in charge-sustaining mode are supplementing battery power with another source of energy, most commonly from a gasoline-powered onboard generator. The battery's state of charge is not being reduced. PHEVs essentially operate in charge-sustaining mode.

Direct-Injection Transmission

A means of increasing power output and fuel efficiency in internal combustion engines. Gasoline is directly injected into the combustion chamber, as opposed to fuel injection, when it is ignited into the air intake.

DriveTrain

Also called the powertrain, the set of components for transmitting power to a vehicle's wheels, including the engine, clutch, torque converter, transmission, drivshafts or axle shafts, U-joints, CV-joints, differential and axles.

EISA 2007


Electric Drive Vehicle (eDV)

An inclusive term that refers to vehicles that incorporate some form of battery electric power in the drivetrain. Includes hybrid electric vehicles (HEVs); plug-in hybrid electric vehicles (PHEVs); extended-range electric vehicles (EREVs); and electric vehicles (EVs).

Electric Motor

Transforms electrical energy into mechanical energy. In a grid-enabled vehicle, the electricity is supplied by the battery or by an onboard home energy generation source.

Electric Vehicle (EV)

A vehicle propelled 100 percent by an electric motor, which forms part of an electric drivetrain. The power comes from a battery or from a combustion engine that powers a generator.

Electric Vehicle Miles Traveled (EVTM)

The number of electric miles traveled nationally for a period of 1 year.

Electric Mile

For an electric vehicle, an electric mile is any mile in which the vehicle is propelled by an electric motor for PHEVs or E-REVs; an electric mile is the total miles traveled multiplied by the percent of total power provided by electricity from the grid.

Electric Vehicle Supply Equipment (EVSE)

The hardware of electric vehicle charging infrastructure, including public charging stations and wall- or pole-mounted home vehicle chargers.

Extended-Range Electric Vehicle (EREV)

Sometimes called series or serial plug-in hybrids. E-REVs are electric drivetrain vehicles that rely on an electric motor to provide power to the drivetrain but which also include a gasoline internal combustion engine serving as an electrical generator to either provide electricity to the vehicle's electric motor (supplementing the battery's stored power) or to maintain the battery's state of charge as it powers depletes. The gasoline engine is not used to directly provide mechanical energy to the drivetrain.

Full Hybrid

Hybrids that provide enough power for limited levels of autonomous, battery-powered driving at slow speeds. Efficiency gains ranging from 25 to 40 percent.

Generator

Converts mechanical energy from an engine into electrical energy.

Grid-enabled Electric Vehicle (GEEV)

Electric or hybrid-electric vehicles that can be plugged directly into the electric grid to recharge onboard batteries.

Internal Combustion Engine (ICE)

An engine that produces power by combining liquid fuel and air at high temperature and pressure in a combustion chamber, resulting in the gas expansion for mechanical energy. Conventional vehicle ICE engines use two-stroke or four-stroke combustion cycles, which combine intermittently.

IEC

An oil company that is fully or majority owned by private investors.

Innovative equipment manufacturer (IEM)

A company that produces a product designed for the end user, whether a consumer or another manufacturing firm. For example, an automotive OEM sells vehicles to consumers, typically through a dealer network; however a battery OEM may sell/batteries only directly to automotive manufacturers.

Peak Demand (or Load)

The greatest electricity demand that occurs during a specified period of time.

Plug-In Hybrid Electric Vehicle (PHEV)

A form of HEV that generally has larger batteries, allowing it to derive more of its propulsion from electrical power than from the ICE engine. PHEVs are, as a result, far more efficient in their use of energy than typical HEVs. These batteries can be recharged by connecting a plug to an external electric power source.

Power Inverter

An electric device that converts direct current (DC) into alternating current (AC) or DC back to DC.

Powertrain

See Drivetrain.

Residual Battery Value

The value of a battery established by the manufacturer after it has completed its primary purpose service life.

Series Hybrid

A vehicle which has an ICE engine and electric motor, but only the electric motor provides power to the wheels. A series hybrid is therefore essentially an electric vehicle with a fossil fuel recharging system on board. Both sources of power can be used if necessary.

Spare Oil Production Capacity

The amount of demand of oil production capacity which could theoretically be brought online within 30 days and which can be sustained for 90 days. Generally, only OPEC members maintain spare production capacity.

Total Cost of Ownership (TCO)

A measure of the entire undiscounted cost associated with the purchase, maintenance, usage, and disposal of a product spread evenly over the expected service life.

Transformer

A device that transfers electrical energy from one circuit to another, converting electricity from one voltage to another, performing the step-down or step-up necessary to enable high voltage, low current transmission, minimizing losses over long distances.

Transmission

Interconnected group of lines and associated equipment for the movement or transfer of electric energy between points of supply and points at which it is transformed for delivery to customers or is delivered to other electric systems.

Vehicle Miles Traveled (VMT)

The number of miles traveled nationally by vehicles for a period of one year.
Partners & Consultants

Securing America’s Future Energy (SAFE) is a nonpartisan, not-for-profit organization committed to reducing America’s dependence on oil and improving U.S. energy security in order to bolster national security and strengthen the economy. SAFE has an action-oriented strategy addressing politics and advocacy, business and technology, and media and public education.

Since 1976, PRTM has created a competitive advantage for its clients by changing the way companies operate. The firm’s management consultants define the strategies and execution required for transformational change, through operational experience across industry value chains and extensive work within the public sector. PRTM has 19 offices worldwide and serves major industry and global public sectors.

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The Fleet Electrification Roadmap is a comprehensive analysis of the state of transportation electrification in the United States and the next steps needed to deliver on the potential of grid-enabled vehicles. The report explores the opportunities and challenges facing electrification of commercial and government fleets, identifies economically attractive opportunities, and outlines a path to driving substantial fleet demand for grid-enabled vehicles between 2010 and 2015.