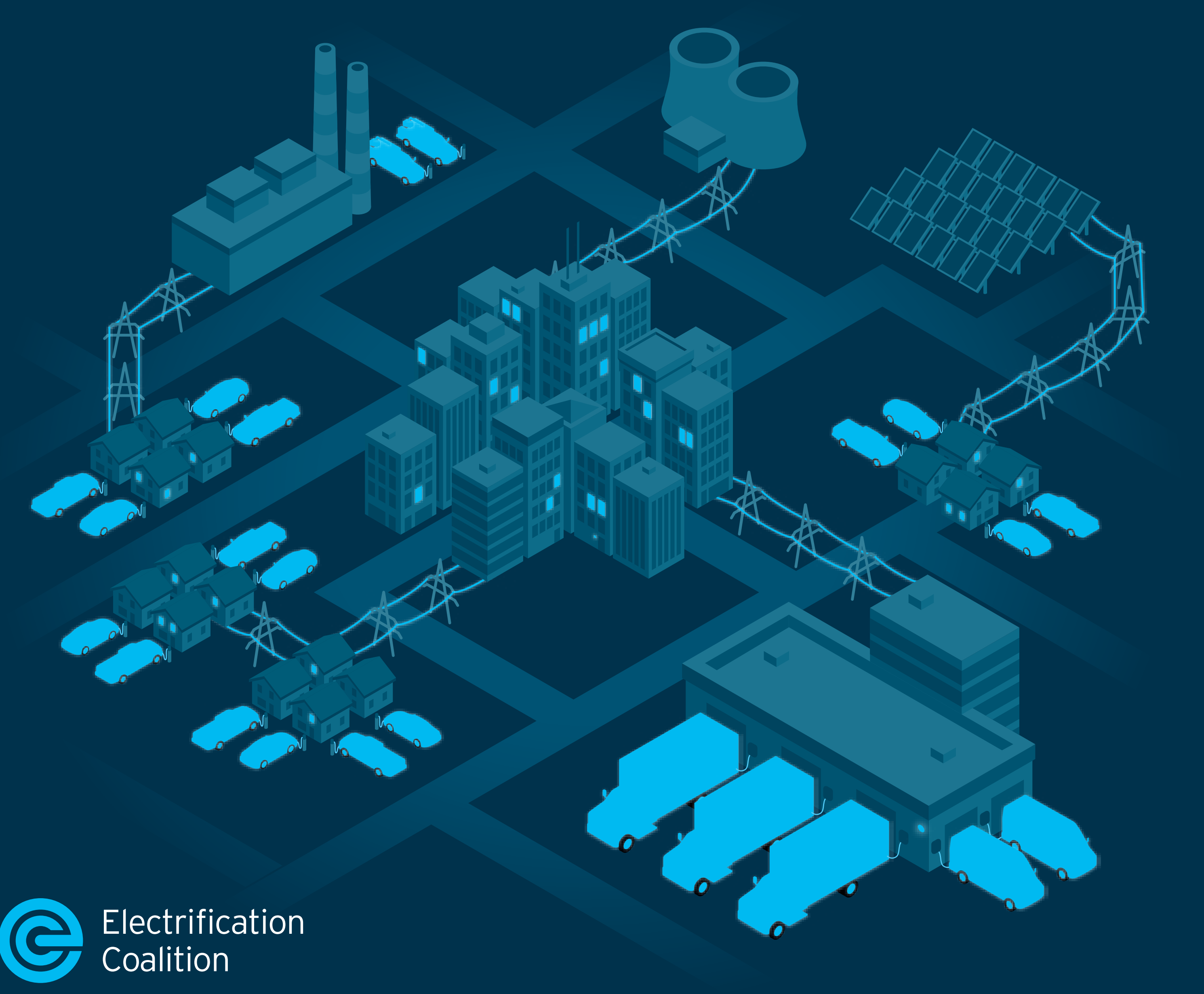
Fleet Electrification Roadmap

REVOLUTIONIZING TRANSPORTATION AND ACHIEVING ENERGY SECURITY

November 2010



Electrification Coalition

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Electrification Coalition

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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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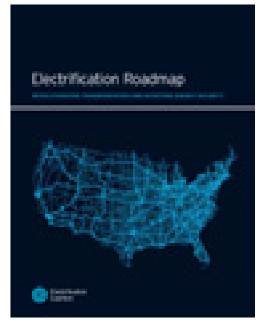
LETTER FROM THE ELECTRIFICATION COALITION



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 PHEVs 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.

> *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.*

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 (today, 94 percent of the delivered energy that powers the U.S. transportation system is petroleum-based).

The strong, targeted consumer incentives envisioned by the Electrification Roadmap were designed to drive economies of scale in the electric drive battery industry, thereby reducing costs. But subsidies could not represent a credible stand-alone policy. Strong support for infrastructure providers was also included to reduce the marginal cost of installing early charging units at home and in public, allowing entrepreneurs to experiment with business models and providing potential GEV customers with confidence that they would be able to reliably and conveniently refuel their vehicles, both at home and in public. 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 off-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 parc 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 surmount 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 advantages the economic dynamics of electric drive vehicles in cases where the higher upfront costs vis-à-vis an internal combustion engine vehicle can be demonstrably offset through lower operating and maintenance costs over time.

Fleet owners may also benefit from operational norms such as centralized refueling, high vehicle utilization rates, 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 fleet 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 vehicle drivers to do their job effectively.

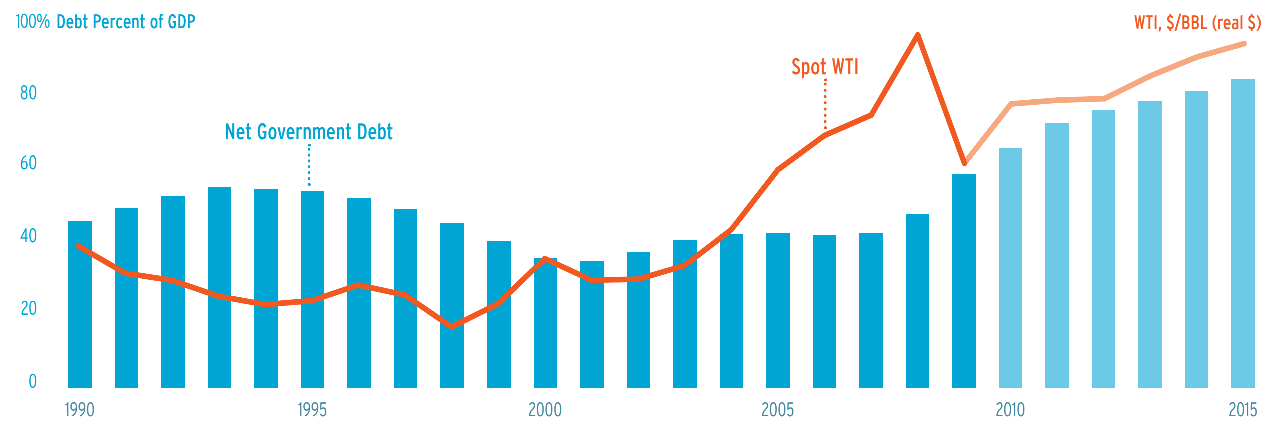
Fleet electrification should not be an end in itself. By driving volume in battery and OEM supply chains, providing practical business experience with both private and public charging infrastructure, and demonstrating the reliability of electric drive vehicles to consumers throughout the United States, 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]

FIGURE E1

Net U.S. Government Debt as a Percentage of GDP



Source: DOE; IMF

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]

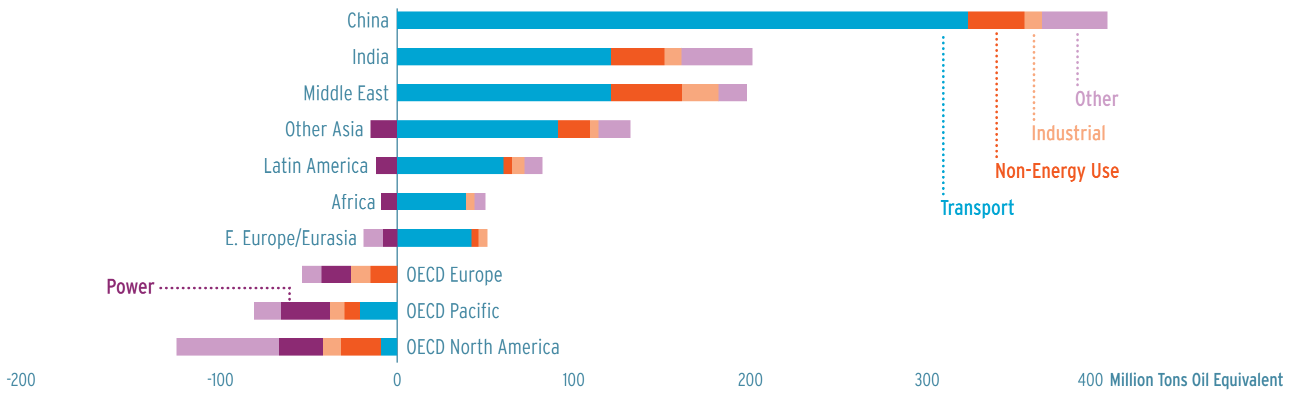
More than 70 percent of the oil we use is for transportation fuels.[6] At approximately 14 million barrels per day, the U.S. transport sector alone consumes more oil than any other national economy in the world.[7] Highway transportation—passenger vehicles, freight trucks, and buses—accounts for the 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] Burgeoning 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

1 U.S. Department of Energy (DOE), Energy Information Administration (EIA), Petroleum Navigator, Monthly Crude Oil Spot Prices, available at http://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm.
2 *Id.*
3 BP, plc, *Statistical Review of World Energy 2010*, at 41.
4 EC analysis based on DOE, Annual Energy Review 2009 (AER 2009), Table 3.5.
5 *Id.*
6 DOE, *AER 2009*, Tables 5.13a through 5.13d.
7 DOE, *AER 2009*, Tables 5.13a through 5.13d; BP, plc, Statistical Review of World Energy 2010, at 11, 12.
8 DOE, Office of Energy Efficiency and Renewable Energy (EERE), *Transportation Energy Data Book 2010*, Table 1.14.
9 DOE, *AER 2009*, Table 2.1e.
10 International Energy Agency, *World Energy Outlook 2010*, Annex A, New Policies Scenario.

FIGURE E2

Change in Primary Oil Demand by Region and Sector (2007-2030)



Source: International Energy Agency, *World Energy Outlook 2009*

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.

70% 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 increase in global oil consumption.

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.[11] 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 production capacity is expected to surpass 350,000 units by 2015.[12] However, the long-term market outlook for these vehicles is somewhat uncertain. To be sure, early adopters and technological enthusiasts will prove to be a reliable customer base for the first several hundred thousand GEVs marketed in the United States. But in order to fully capitalize on the potential of electrification to fundamentally improve U.S. energy and economic security, broader market penetration is required.

11 U.S. Department of Commerce, Census Bureau, Foreign Trade Statistics, available at http://www.census.gov/indicator/www/ustrade.html.

12 PRTM analysis.

FIGURE E3

Annual Fleet GEV Sales Scenarios

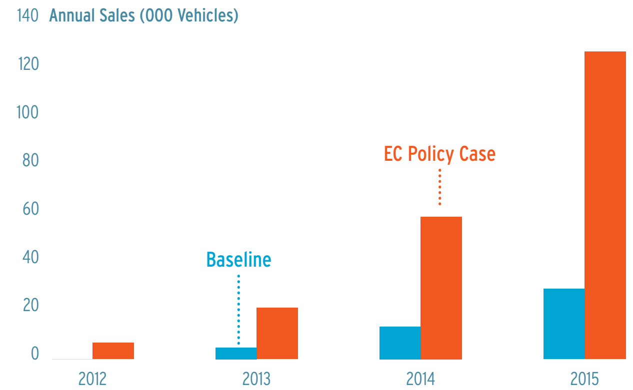
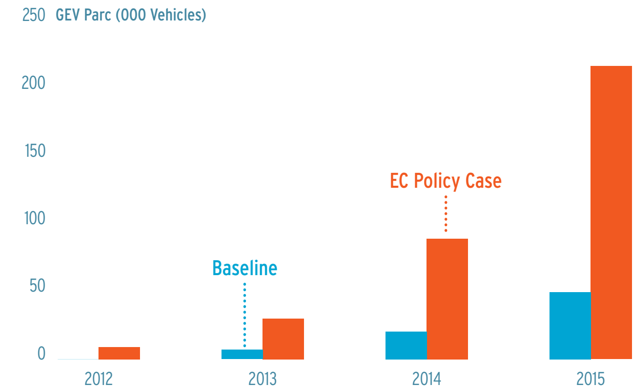


FIGURE E4

Fleet GEV Parc Scenarios



Source: PRTM Analysis

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.

PART ONE

The Case for Fleets

There were more than 16 million public and private fleet vehicles on the road in the United States in 2009.[13] While the size of individual fleets varies significantly, the top 50 fleet operators together manage more than half a million cars and trucks.[14] 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 postal 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 ownership in anticipation of reaping financial benefits down the road.

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.[15] Consumers, on the other hand, may purchase for a variety of reasons, including aesthetics and style, in addition to cost.

Route Predictability: The most cost-intensive component in current-generation electric drive vehicles is the battery. 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 added upfront investment in excess energy storage.

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. GEVs can help meet reduced emissions and petroleum consumption goals.

13 PRTM analysis; This figure is derived from a composite of data sources, including R.L. Polk & Co., Automotive Fleet, U.S. General Services Administration, GE Capital, Utilimarc, and others.

14 Bobit Publishing Company, 2010 Automotive Fleet Factbook (AFB), available online at http://www.automotive-fleet.com/Statistics/.

15 EC, PRTM interviews with fleet managers.

PART TWO

Fleet Challenges

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.

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.

Fleet Infrastructure Issues: Even for fleets that centrally park, the cost of installing charging infrastructure may be significant. With Level II charger costs averaging $2,000 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.

PART THREE

Identifying Fleet Opportunities

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 applies to class 4-5 medium-duty trucks; and $25,000 tax credits applied to class 6-7 heavy-duty trucks. (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

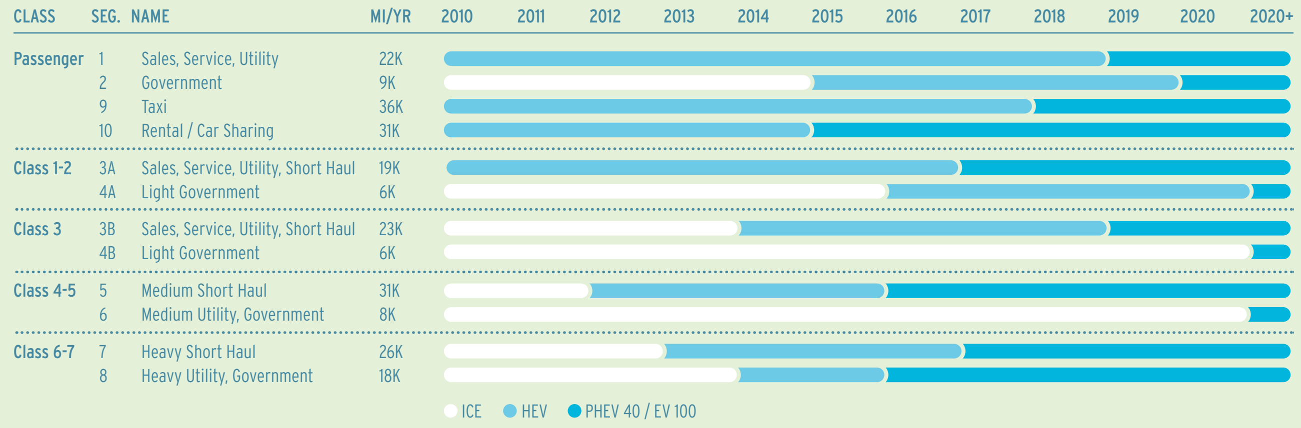


FIGURE E6

Lowest TCO Drivetrain Technology by Year and Segment - Operations Optimized

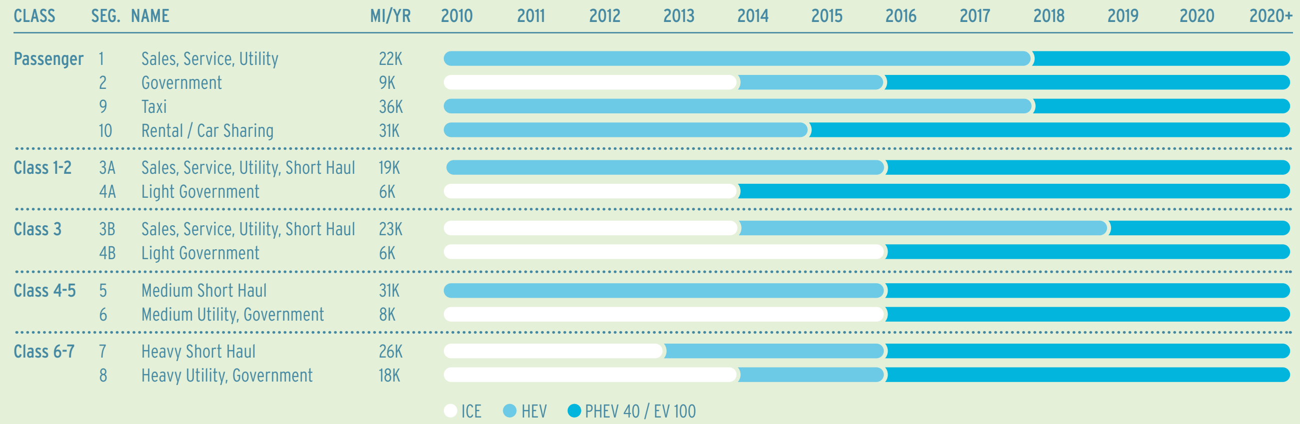
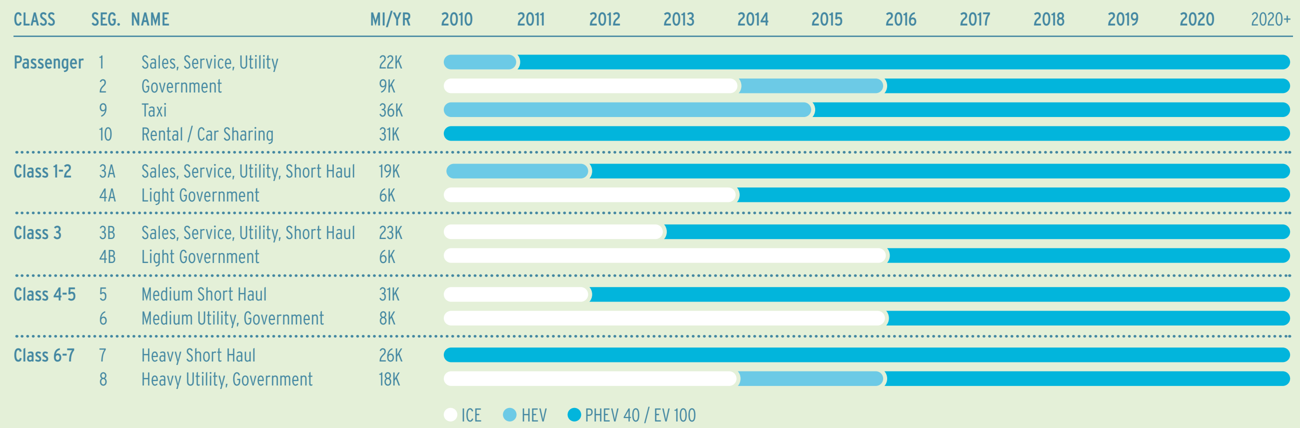


FIGURE E7

Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized + Government Incentives



Source: PRTM analysis

PART FOUR

Policy Recommendations

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 telecom 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.

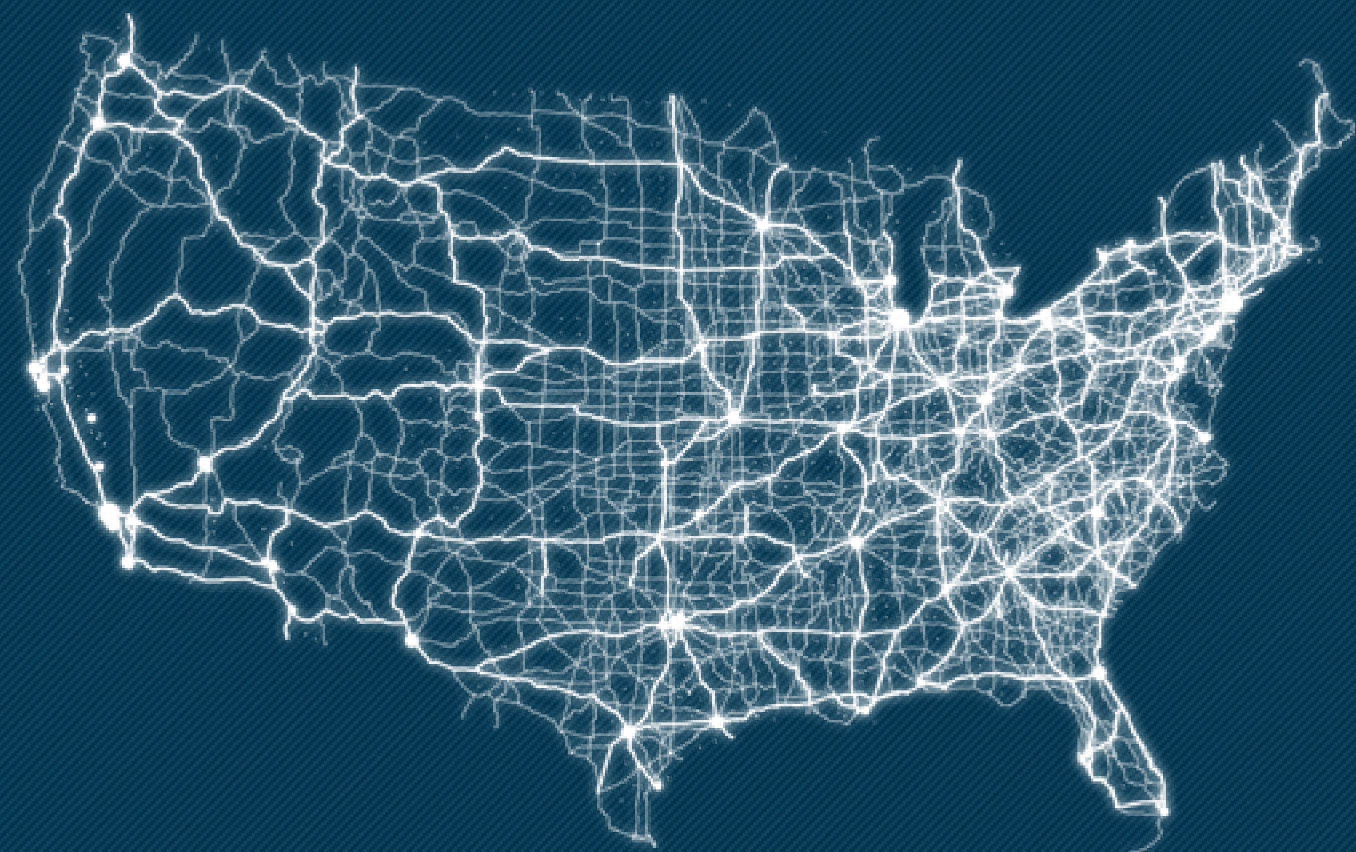
Increase federal investment in advanced battery research and development.

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.

PRIMER

Electrification of the Transportation Sector



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.

Want To Learn More?

Visit ElectrificationCoalition.org to download the Electrification Roadmap or request a printed copy.

Overview

Two years after Congress passed and the president signed the American Recovery 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 engrained 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.[1] Nearly 20 other awardees received a total of $356 million in transportation electrification funds.[2]

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 $417 dollars per kWh from five upward, capping at an additional $5,000. 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.[3]

In addition, the Department of Energy (DOE) distributed $300 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

A worker checks production of lithium-ion automotive batteries in a Johnson Controls Advanced Power Solutions plant.

Indiana. By 2012, 30 factories with the capacity to produce an estimated 20 percent of the world's advanced vehicle batteries will exist in the United States.[4] 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).[5]

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.[6] Nissan has announced plans for a wider market launch beginning in 2011.[7] 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.[8] A number of other significant plug-in offerings from start-up vehicle manufacturers such as Coda, Bright, and

1 U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), *Recovery Act Awards for Electric Drive Vehicle Battery and Component Manufacturing Initiative*, available at http://www1.eere.energy.gov/recovery/pdfs/battery_awardee_list.pdf, last accessed October 27, 2010.

2 DOE, EERE, *Recovery Act Awards for Transportation Electrification*, available at http://www1.eere.energy.gov/recovery/pdfs/battery_awardee_list.pdf, last accessed on October 27, 2010.

3 American Recovery and Reinvestment Act (ARRA), Section 1141.

4 The White House, *The Recovery Act: Transforming the American Economy through Innovation* (August 2010), available at http://www.whitehouse.gov/sites/default/files/uploads/Recovery_Act_Innovation.pdf, last accessed October 27, 2010.

5 *Id.*

6 Edmunds Daily, "Nissan Leaf Begins Production In Japan, U.S. Deliveries in December," available at http://blogs.edmunds.com/strategies/2010/10/nissan-leaf-begins-production-in-japan-us-deliveries-in-december.html, (October 22, 2010); and ABC News, "New Chevy Ad Campaign to Draw on History, Future," available at http://abcnews.go.com/Business/wireStory?id=11985920, (October 27, 2010).

7 Autoblog, "Nissan announces Leaf rollout plans, 8-year battery warranty," available at http://www.autoblog.com/2010/07/27/nissan-announces-leaf-rollout-plans-8-year-battery-warranty/, (July 27, 2010).

8 Clean Fleet Report, "Ford Plans both Electric Vehicles and Hybrids," available at http://www.cleanfleetreport.com/hybrid-cars/ford-electric-vehicles-plug-in-hybrids/, (October 15, 2009).

FIGURE P1

Electrification Industry Recipients of ARRA Awards

Cell, Battery, and Materials Manufacturing Facilities

1 **$299 Million**
Johnson Controls, Inc

2 **$249 Million**
A123 Systems, Inc.

3 **$161 Million**
KD ABG MI, LLC (Dow Kokam)

4 **$151 Million**
Compact Power, Inc. (on behalf of LG Chem, Ltd.)

5 **$118 Million**
EnerDel, Inc.

6 **$106 Million**
General Motors Corporation

7 **$96 Million**
Saft America, Inc.

8 **$34 Million**
Exide Technologies with Axion Power International

9 **$33 Million**
East Penn Manufacturing Co.

Advanced Battery Supplier Manufacturing Facilities

10 **$49 Million**
Celgard, LLC, a subsidiary of Polypore

11 **$35 Million**
Toda America, Inc.

12 **$28 Million**
Chemetall Foote Corp.

13 **$27 Million**
Honeywell International Inc.

14 **$25 Million**
BASF Catalysts, LLC

15 **$21 Million**
EnerG2, Inc.

16 **$21 Million**
Novolyte Technologies, Inc.

17 **$13 Million**
FutureFuel Chemical Company

18 **$11 Million**
Pyrotek, Inc.

19 **$5 Million**
H&T Waterbury DBA Bouffard Metal Goods

Advanced Lithium-Ion Battery Recycling Facilities

20 **$10 Million**
TOXCO Incorporated

Electric Drive Component Manufacturing Facilities

1 **$105 Million**
General Motors Corporation

2 **$89 Million**
Delphi Automotive Systems, LLC

3 **$63 Million**
Allison Transmission, Inc.

4 **$63 Million**
Ford Motor Company

5 **$60 Million**
Remy, Inc.

6 **$45 Million**
UQM Technologies, Inc.

7 **$40 Million**
Magna E-Car Systems of America, Inc.

Electric Drive Subcomponent Manufacturing Facilities

8 **$15 Million**
KEMET Corporation

9 **$9 Million**
SBE, Inc.

10 **$8 Million**
Powerex, Inc.

Advanced Vehicle Electrification

1 **$100 Million**
Electric Transportation Engineering Corp. (ETEC)

2 **$70 Million**
Chrysler LLC

3 **$45 Million**
South Coast Air Quality Management District (SCAQMD)

4 **$39 Million**
Navistar, Inc. (Truck)

Transportation Sector Electrification

5 **$22 Million**
Cascade Sierra Solutions

Advanced Vehicle Electrification + Transportation Sector Electrification

6 **$31 Million**
General Motors

7 **$30 Million**
Ford Motor Company

8 **$10 Million**
Smith Electric Vehicles

Advanced Electric Drive Vehicle Education Program

9 **$7 Million**
West Virginia University (NAFTC)

10 **$6 Million**
Purdue University

11 **$5 Million**
Colorado State University

12 **$5 Million**
Missouri University of Science and Technology

13 **$5 Million**
Wayne State University

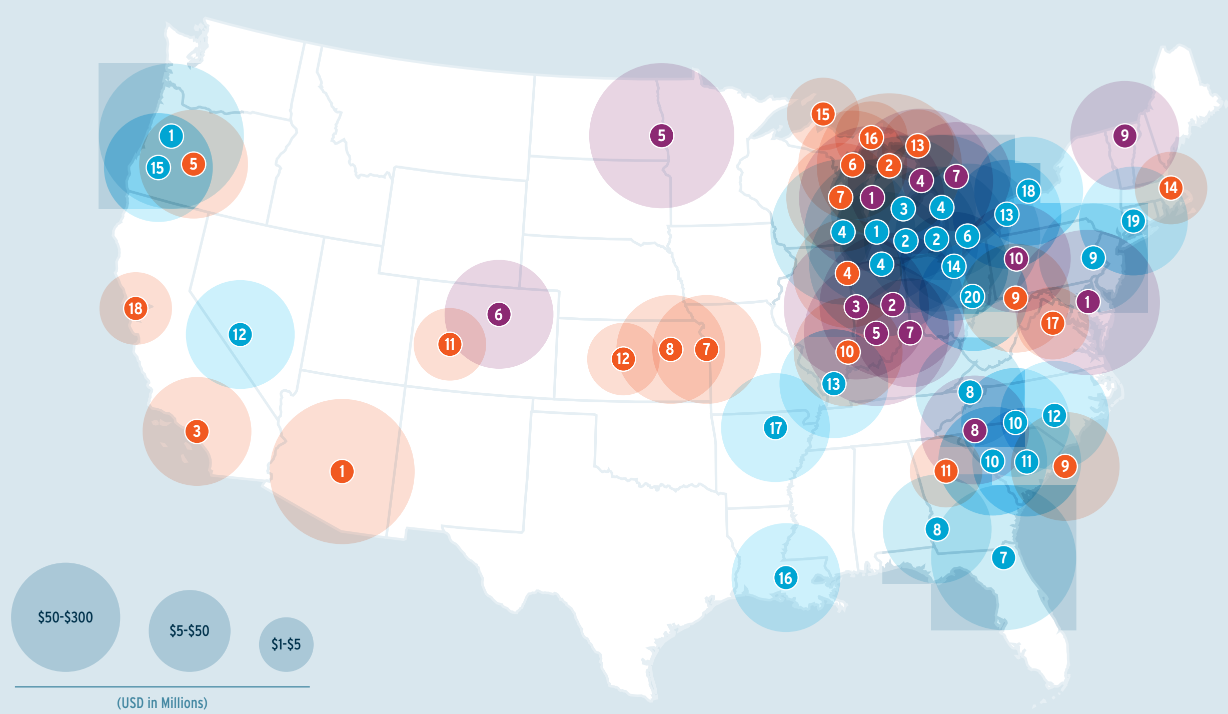
14 **$4 Million**
National Fire Protection Association

15 **$3 Million**
Michigan Technological University

16 **$3 Million**
University of Michigan

17 **$0.72 Million**
J. Sargeant Reynolds Community College

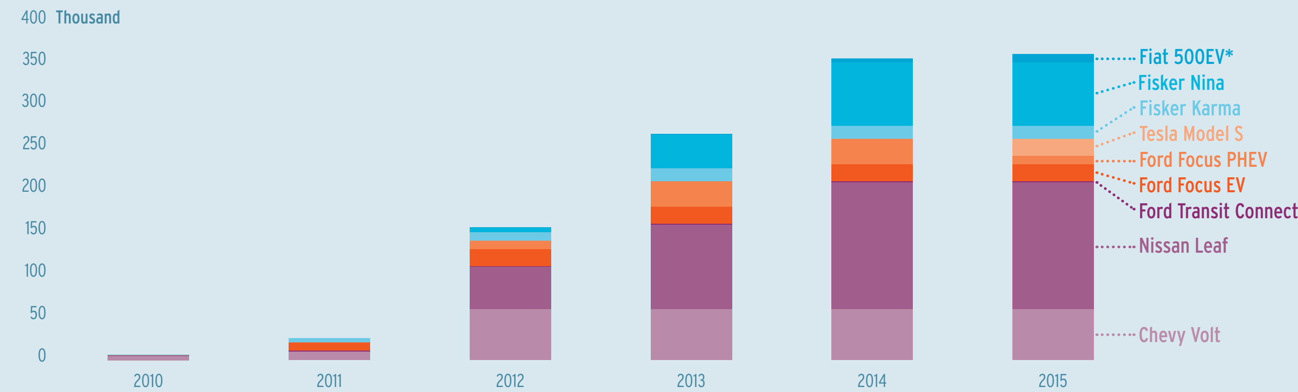
18 **$0.5 Million**
City College of San Francisco



Source: DOE; EC Analysis

FIGURE P2

Currently Announced North American EV and PHEV Production Capacity



Source: PRTM Estimates

Fisker Automotive will bring currently announced North American GEV capacity to 150,000 units by 2012 and nearly 350,000 units by 2015.[9]

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 reaches higher production volumes than currently exist, but the 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.

9 PRTM Analysis.

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.[10] 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.[11] In 2008 and 2009, oil consumption in the United States experienced two consecutive years of decline for the first time in 19 years.[12] Total petroleum supplied is slightly up in 2010 at 19.3 mbd, but is still well below recent averages.[13] 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.[14]

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 230 million light-duty vehicles on U.S. roads today, accounting for approximately 40 percent of total oil consumption.[15] Freight trucks add another 8.7 million vehicles, equaling roughly 12 percent of oil demand.[16] All told, the transportation sector accounts for 71 percent of aggregate U.S. oil consumption.[17] Despite significant efforts to drive alternative fuels into the marketplace, 94 percent of delivered energy in the transport sector is still petroleum-based today.[18]

94% of energy delivered to the U.S. transportation system is petroleum-based today.

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.[19] 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.[20]

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.[21] 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 13.4 percent increase in light-duty vehicle miles traveled.[22] Freight miles traveled are expected to increase by a staggering 51 percent by 2035.[23]

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.[24] 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.

10 BP, plc, *Statistical Review of World Energy 2010*, at 11, available online at www.bp.com; SAFE Analysis.
11 *Id.*
12 *Id.*
13 DOE, Energy Information Administration (EIA), *Weekly Petroleum Status Report*, October 6, 2010, Table 1.
14 Securing America's Future Energy, "SAFE Intelligence Report: Has the U.S. Reached Peak Demand," (October 5, 2010), volume 3, issue 12.
15 DOE, EIA, *Annual Energy Outlook 2010 (AEO 2010)*, Table A-7 and online supplemental table 58, available at http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html, last accessed October 27, 2010.
16 DOE, EIA, *AEO 2010*, online supplemental Table 67.
17 DOE, *Annual Energy Review 2009 (AER 2009)*, Figure 5.0.
18 *Id.*, Table 2.1e.
19 BP, plc, *Statistical Review of World Energy 2010*, at 41.
20 SAFE analysis based on data from DOE, *AEO 2010*, Table 3.5; BP, plc., *Statistical Review of World Energy 2010*; DOE, EIA, *October Short Term Energy Outlook*; and U.S. Bureau of Economic Analysis.
21 DOE, *AEO 2010*, Table A-11; SAFE analysis.
22 *Id.*, online supplemental table 60.
23 *Id.*, online supplemental table 67.
24 DOE, *Transportation Energy Data Book 2009 (TEDB 2009)*, Table 1.14, available at http://www-cta.ornl.gov/data/index.shtml, last accessed on October 27, 2010.

FIGURE P3
Liquid Fuel Consumption, Historical and Forecast

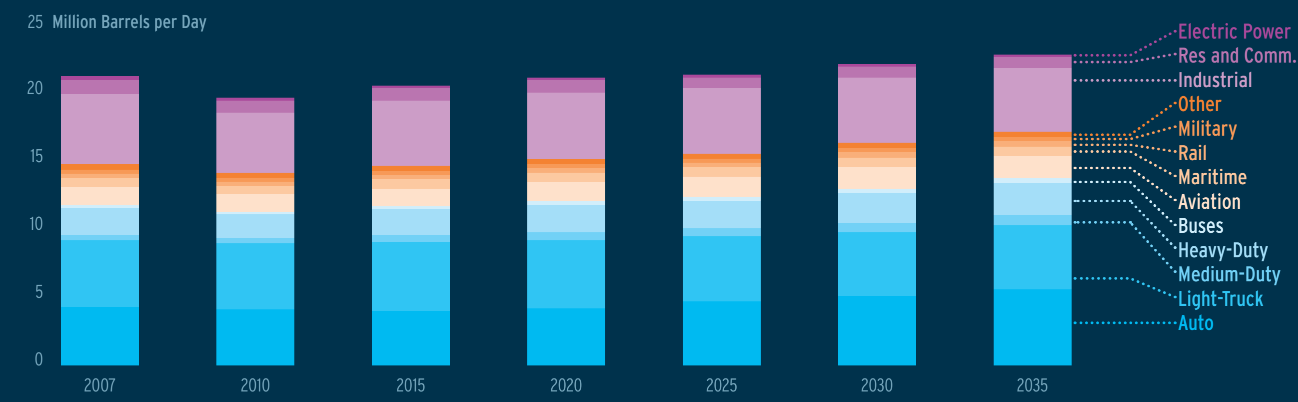


FIGURE P4
Change in U.S. Petroleum Consumption

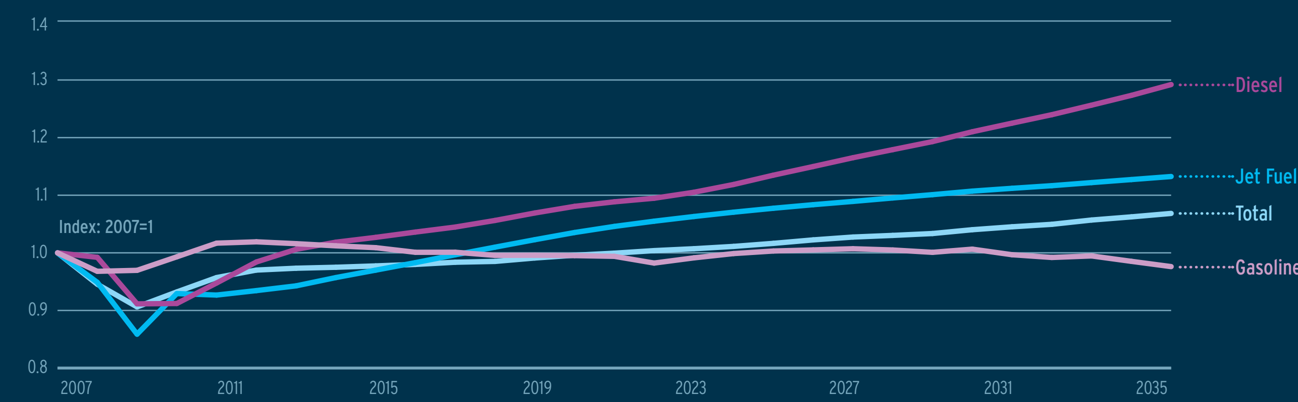
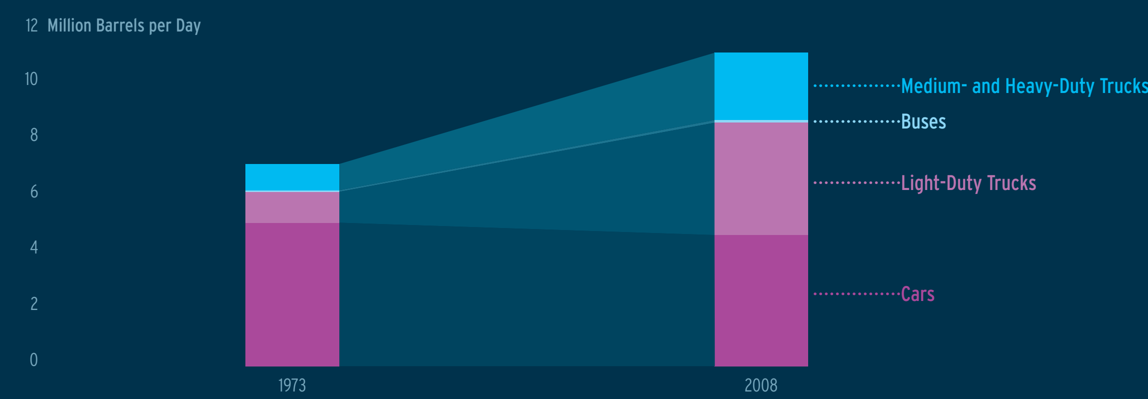


FIGURE P5
Change in U.S. Petroleum Demand, 1973-2008



Source: Figure P3 – DOE, ORNL, TEDB Ed. 29; Figure P4 – DOE, AEO 2010; Figure P5 – DOE, ORNL, TEDB Ed. 29

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.[25] America now imports 58 percent of the oil it consumes, at tremendous cost to the current account balance.[26] 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.[27] 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.[28]

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.[29] For the full year, oil trade accounted for 56 percent of the total U.S. trade deficit in 2008 and 55 percent in 2009.[30] 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 Unites States has little else in the way of economic relationships.[31] 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.

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

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.[32] For 2008 alone, the cost was nearly $500 billion.[33]

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.

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

25 DOE, *AER 2009*, Figure 5.2.
26 *Id.*, Tables 5.1 and 3.9.
27 *Id.*, Table 3.9.
28 DOE, EIA, *October 2010 Short Term Energy Outlook*; and DOE, EIA, *Weekly Petroleum Status Report* (October 6, 2010); SAFE analysis.
29 U.S. Census Bureau, Office of Foreign Trade Statistics; EC analysis.
30 *Id.*
31 DOE, *AER 2009*, Table 5.4.

32 DOE, EERE, Vehicle Technologies Program, *The Cost of Oil Dependence*, available at http://www1.eere.energy.gov/vehiclesandfuels/facts/2010_fotw632.html, last accessed October 27, 2010.
33 *Id.*

FIGURE P6

Monthly U.S. Trade Deficit

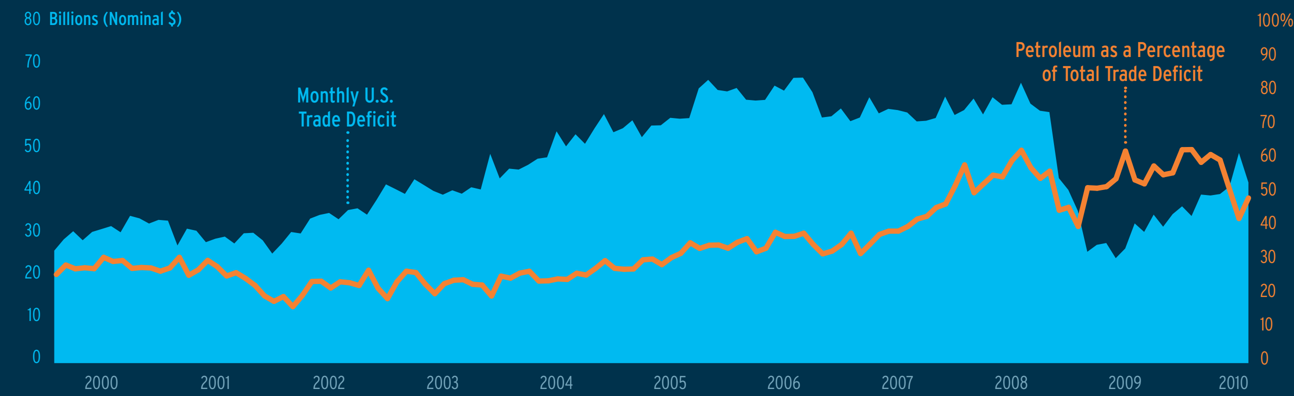


FIGURE P7

Oil Prices And Economic Growth

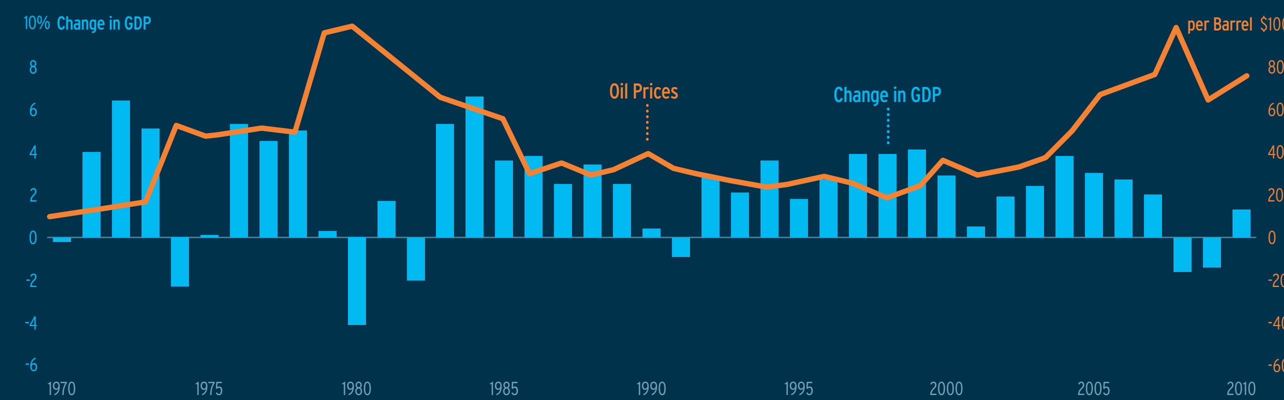
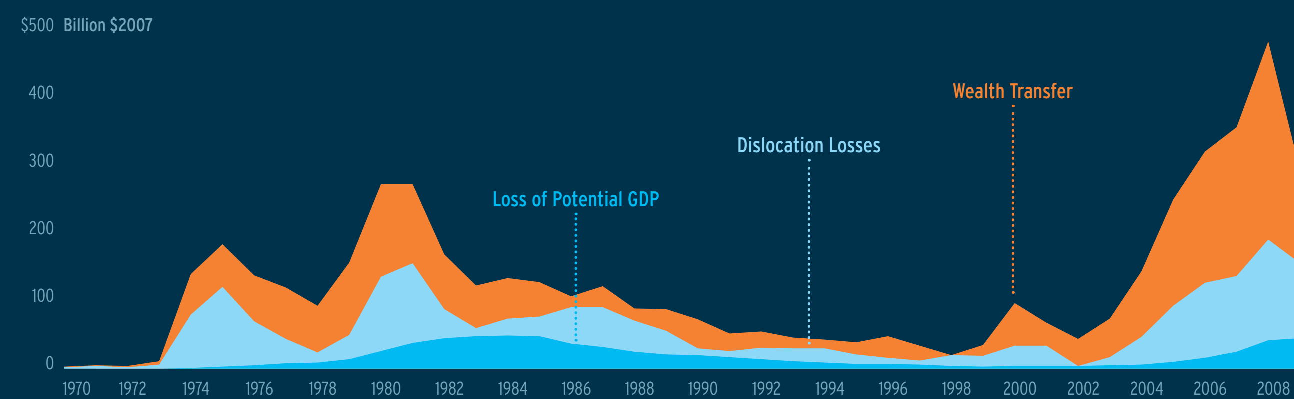


FIGURE P8

Economic Costs of U.S. Oil Dependence



Source: Figure P6 — U.S. Census Bureau; Figure P7 — U.S. Bureau of Economic Analysis; Figure P8 — Greene, David L., and Janet L. Hopson, "The Costs of Oil Dependence 2009"

National Security Costs

The importance of oil has given it a place of prominence in foreign and military policy. In particular, two key issues related to oil affect national security. First, the vulnerability of global oil supply lines and infrastructure has driven the United States to accept the burden of securing the world's oil supply. Second, the importance of large individual oil producers constrains U.S. foreign policy options when dealing with problems in these nations.

A crippling disruption to global oil supplies ranks 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.[34] 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 infrastructure 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.[35] 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.

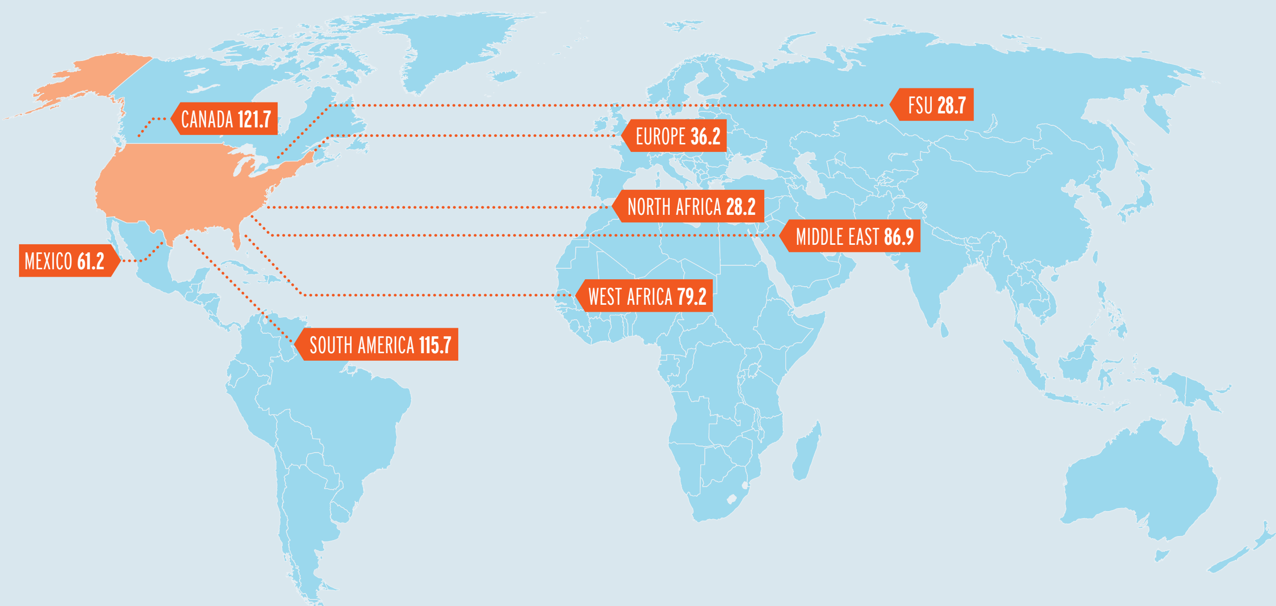
Foreign policy constraints related to oil dependence are less quantifiable, but no less damaging. Whether dealing with uranium enrichment in Iran, a hostile regime in Venezuela, or an increasingly assertive Russia, American diplomacy is distorted by our need to minimize disruptions to the flow of oil. 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.

34 RAND Corporation, "Imported Oil and U.S. National Security," at 60-62 (2009).

35 *Id.*, at 71.

FIGURE P9

Global Map of Major U.S. Petroleum Imports (Million tonnes)



Source: BP, plc, *Statistical Review of World Energy 2010*, at 21

Environmental Sustainability

The environmental externalities of oil production and consumption are increasingly coming into focus. Total U.S. energy-related CO_2 emissions were 5,405 million metric tons in 2009.[36] Emissions from the combustion of petroleum accounted for 43 percent of the total, representing a significantly larger share than emissions from coal use.[37]

From a sectoral perspective, electric power represents the largest source of energy-related CO_2 emissions, accounting for 2,152 million metric tons in 2009.[38] Coal emissions make up more than 80 percent of the total U.S. power emissions profile.[39] 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. CO_2 emissions, having surpassed industrial emissions in 1999.[40] Total CO_2 emissions from transportation were 1,851 million metric tons in 2009, and 98 percent of these emissions were from petroleum consumption.[41] In 2009, consumption of petroleum in the transportation sector accounted for more U.S. energy-related CO_2 emissions than the consumption of coal for electric power production.[42]

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 CO_2 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.

43% 2009 energy-related CO_2 emissions attributed to petroleum.

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

36 DOE, *AER 2009*, Table 12.1.
37 DOE, *AER 2009*, Table 12.2.
38 *Id.*
39 *Id.*
40 *Id.* Table 12.3.

41 *Id.*
42 *Id.* Tables 12.2 and 12.3.

Traffic on Interstate-35E and Dallas Skyline.

FIGURE P10

Share of Energy-Related CO_2 Emissions by Fuel & Use

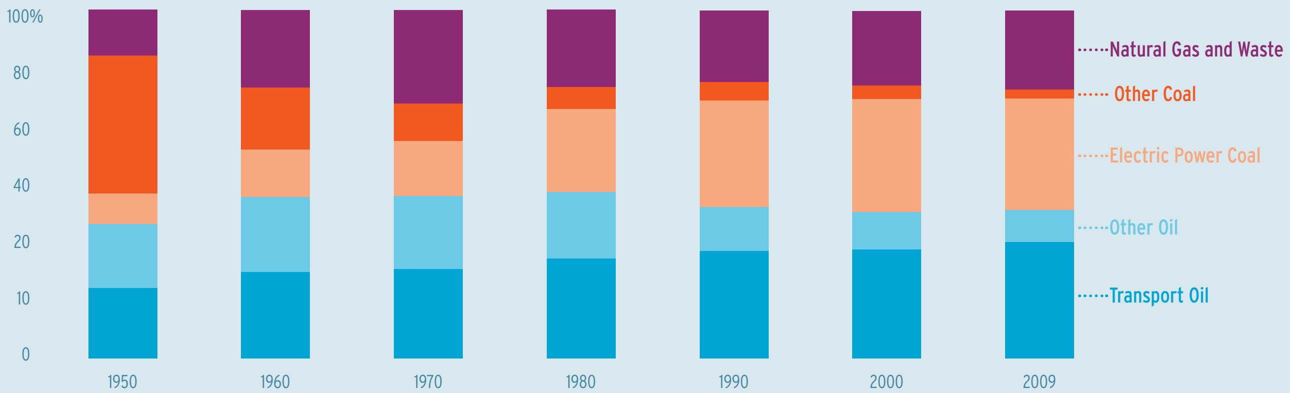
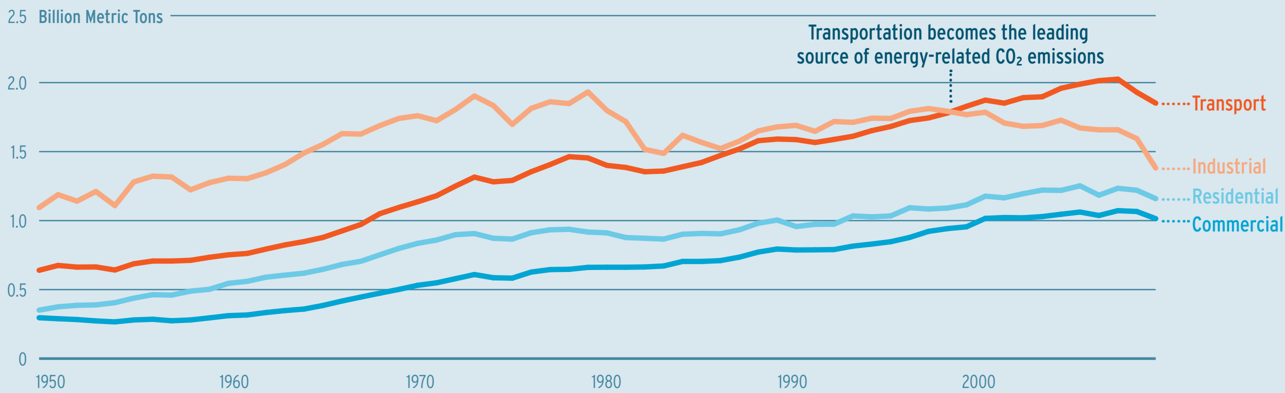


FIGURE P11

Energy Related CO_2 Emissions, End Use



Source: Figure P10 – DOE, *AER 2009*; Figure P11 – DOE, *AER*

rig—Deepwater Horizon—sank in approximately 5,000 feet of water. The accident severed the rig's connection to the seafloor, and the blowout preventer also experienced a complete failure. While estimates vary considerably, the oil spill that resulted from the Deepwater Horizon incident likely released several million barrels of crude oil into the Gulf of Mexico before the damaged well was stabilized on July 15.

Like any business, the global oil and gas industry is not risk-free. The availability of relatively inexpensive conventional oil and gas supplies is dwindling in the regions most accessible to international oil companies—the United States, Western Europe, and industrialized Asia-Pacific. To be sure, low-cost proven oil reserves still exist in substantial quantities, but they are most commonly located in countries or regions that do not permit IOCs to operate freely. As a result, IOCs have increasingly expanded the boundaries of technological possibilities in the regions in which they can operate.[43]

Finding and developing these fuels is costly and technologically complex, and deepwater oil and gas exploration is expected to be at the forefront of industry efforts to expand upstream petroleum production in the coming decades. Significant discoveries off the coast of Brazil, Greenland, Canada, and West Africa are among the promising opportunities to produce the fuels that drive the global economy today—and probably will for some time. And yet, the environmental risks associated with these projects should be an important consideration for policymakers. Catastrophic oil spills are extremely low-probability events. But they are also extremely high-cost events.

43 International Energy Agency (IEA), *World Energy Outlook 2008 (WEO 2008)*, Table 14.1.

Assessing Energy Markets over the Medium Term

The factors that led to high oil prices and increased volatility 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 reshaping 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 shrunk 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]

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 29, 2010.

45 BP, plc., *Statistical Review of World Energy 2010*, at 11.

46 Neil King, "An oil thirsty America dived into 'dead sea,'" Wall Street Journal, October 9, 2010.

Emerging market demand growth is placing new pressures on oil supplies. In large part, the high level of oil price volatility beginning in 2003 resulted from oil producers' inability to adequately respond to the sharp increase in demand driven by emerging market economies. Rapidly escalating oil consumption in China, India, and the Middle East stressed the global oil production system to its limits. In the meantime, resource nationalism, political instability, and insufficient upstream investment in many oil producing regions led to constrained growth in oil supplies. The result was a rapid erosion of spare capacity within OPEC to extremely low levels—less than 2 percent of global demand.[47] In such an environment, even small perturbations or changes in market assessments about the balance between supply and demand can cause sharp price swings in crude oil and retail fuels.

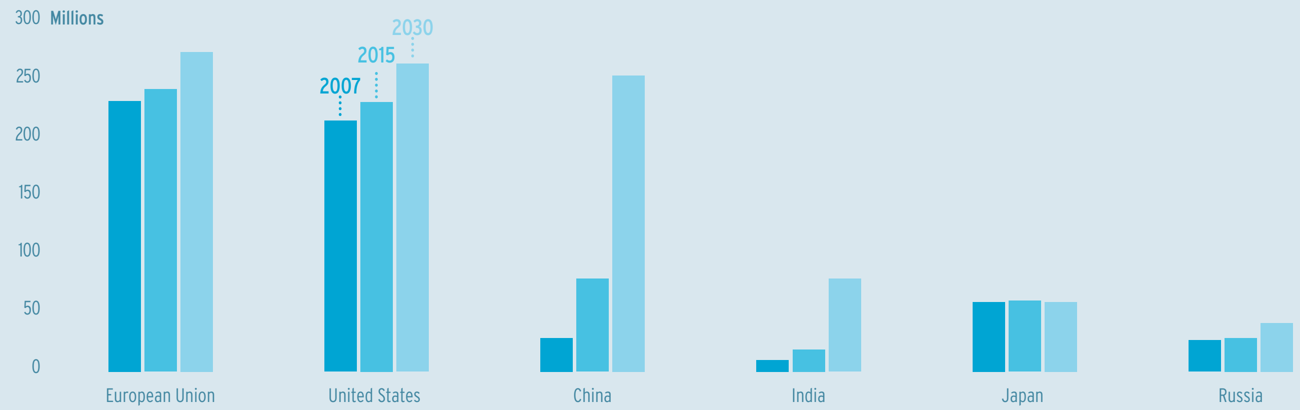
Going forward, analysts expect oil demand growth in the Chinese, Indian, and Middle Eastern transport sectors to make up more than 70 percent of the increase in global oil consumption between 2010 and 2030.[48] Today, there are approximately 30 million light-duty vehicles on the road in China; by 2030, analysts expect that number to increase nearly 10-fold (see Figure P12). At the same time, growth in global oil supplies will be tenuous. Oil

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 29, 2010.

48 IEA, *WEO 2009*, Table 1.3.

FIGURE P12

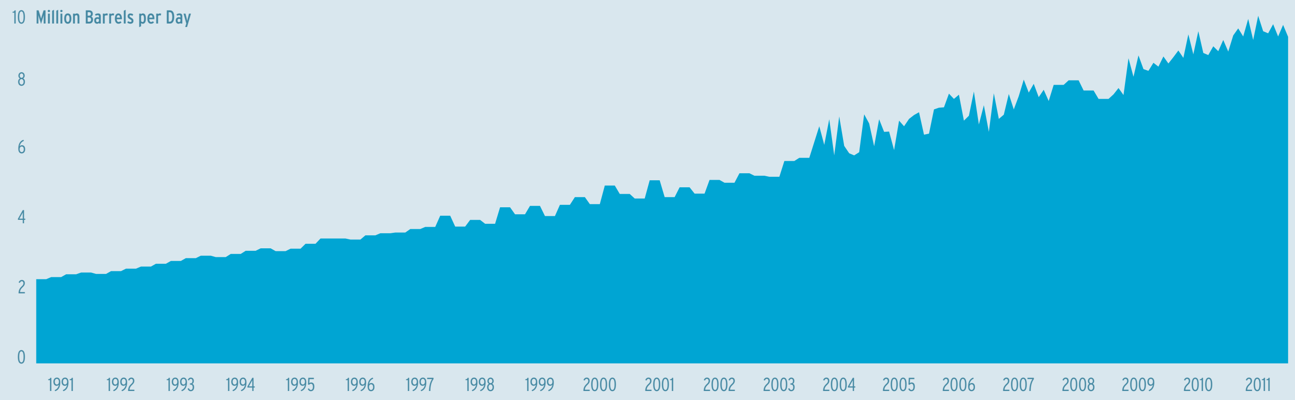
Light Duty Vehicle Stock by Region



Source: International Energy Agency, World Energy Outlook 2009

FIGURE P13

Oil Demand, China



Sources: DOE, EIA

production within the world's most developed nations—the 30 members of the Organization for Economic Cooperation and Development (OECD)—peaked in 1997 and has markedly declined each year since 2002.[49] 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).[50] 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.[51]

Meanwhile, the fraction of global oil reserves that is accessible to international oil companies (IOCs) is growing increasingly complex and costly to produce.[52] 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.[53] For projects in the Gulf of Mexico, marginal costs are estimated to be $60 per barrel.[54] 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, notional OPEC spare capacity is currently 5.1 million barrels per day, a level last witnessed throughout 2001 and 2002, when oil prices averaged $20 to $30 per barrel.[55] 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.[56] 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.

49 BP plc, *Statistical Review of World Energy 2009*, at 8.
50 IEA, *WEO 2008*, Table 14.1.
51 Valerie Marcel, "States of Play," Foreign Policy (Sept/Oct 2009).
52 IEA, *WEO 2008*, at 343-53 (2008); Bernstein Research, "Global Integrated Oils: Breaking Down the Cost Curves of the Majors, and Developing a Global Cost Curve for 2008," at 14 - 34 (Feb. 2, 2009).
53 Bloomberg Business Week, "Production Costs Climb for Canadian Oil Sands, Companies Say," June 2, 2010.
54 DOE, EIA, "Performance Profiles of Major Energy Producers 2008," at 24 (December 2009).
55 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 29, 2010.
56 DOE, EIA, *Weekly Petroleum Status Report* (October 6), available at http://www.eia.gov/pub/oil_gas/petroleum/data_publications/weekly_petroleum_status_report/historical/2010/2010_10_06/wpsr_2010_10_06.html, last accessed October 29, 2010.

The Case for Electrification

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.[57] 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 electricity. 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 battery 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. energy security. However, grid-enabled vehicles offer an entirely new prospect: a transportation system delinked 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 technology itself.

Electrification of transportation remains the most promising near-term opportunity for fundamentally reducing America's dependence on oil.

57 The Honda Insight was introduced in the U.S. in 1999 followed by the Toyota Prius in 2000. Fuel efficiency improvement figures can vary widely based on the method of comparison. According to DOE's *2010 Fuel Economy Guide* (http://www.fueleconomy.gov/feg/FEG2010.pdf), a Ford Fusion FWD Ice vehicle rates at 22/31 mpg city/hwy. The Fusion Hybrid FWD rates at 41/36. Using a weighted harmonic mean, the efficiency improvement in combined mpg would be 49 percent. In comparison, the Toyota Prius rates at 51/48 mpg.

FIGURE P14

Electrification Architecture

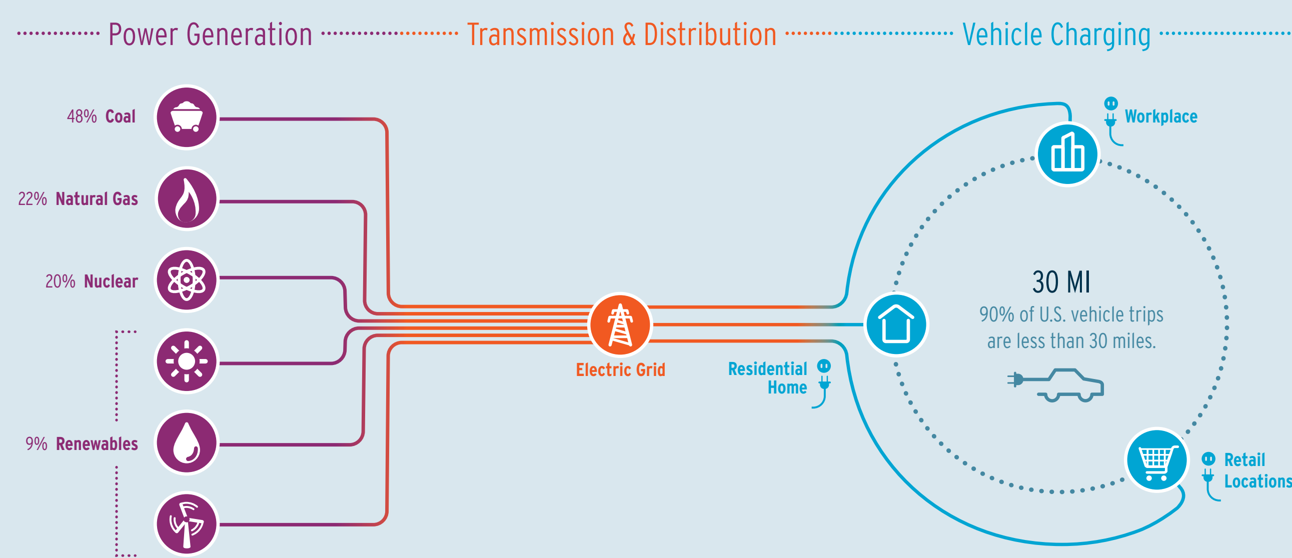
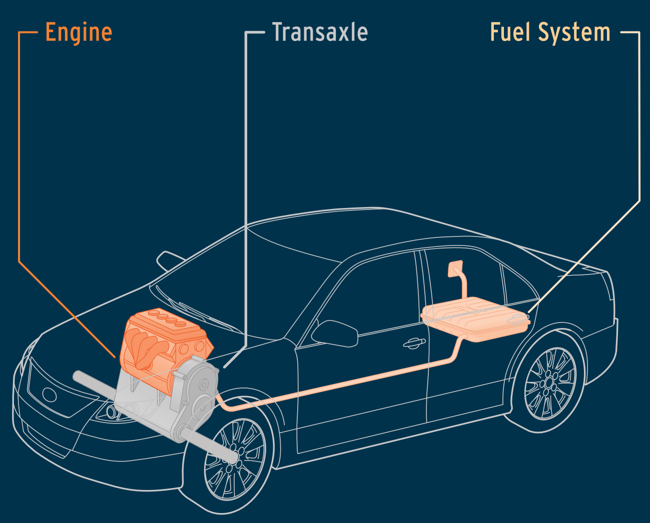


FIGURE P15

Vehicle Configurations

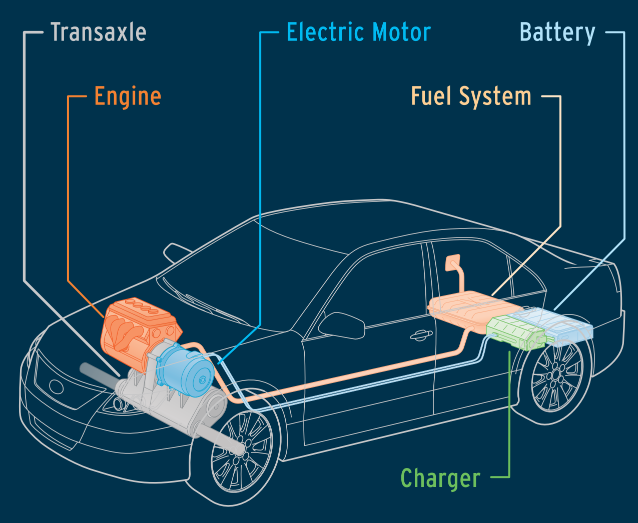
INTERNAL COMBUSTION ENGINE VEHICLE



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.

HYBRID-ELECTRIC VEHICLE (HEV)



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.

HYBRID ELECTRIC VEHICLE SYSTEMS

MILD HYBRID (PARALLEL SYSTEM)

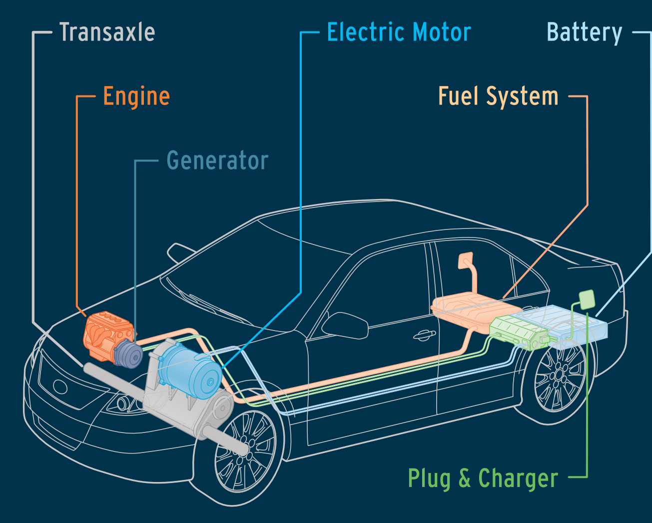
- Still relies heavily on IC engine
- Efficiency gains of 15 to 20 percent
- Battery provides additional power during acceleration; powers the A/C and other systems during idling
- Regenerative braking charges battery

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

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.

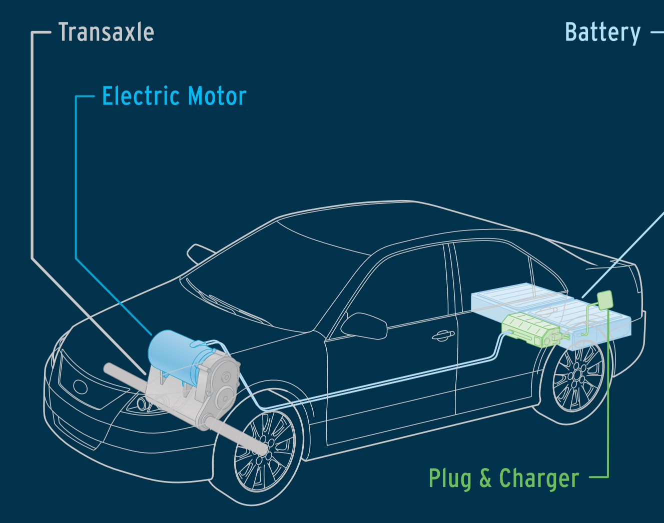
PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)



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.

ELECTRIC VEHICLE (EV)



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.

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 used to generate electricity, even accounting for line losses in transmitting the electricity from the power plant.

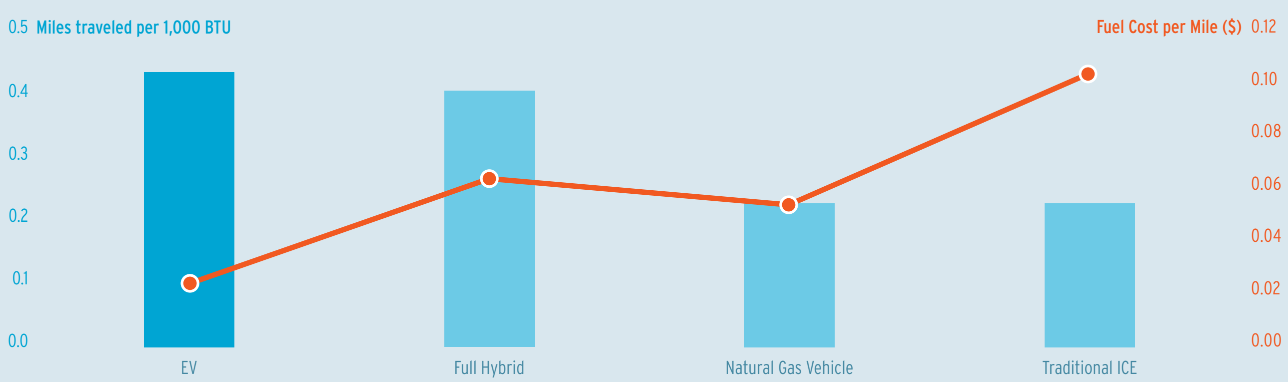
Reduced Emissions: Electric drive technology can provide significant reductions in CO_2 emissions compared to conventional vehicles powered by fossil fuels. Today's full hybrids offer as much as a 30 percent improvement in emissions when compared to similarly sized conventional gasoline vehicles. Questions 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.[58] Together with natural gas, fossil fuels account for as much as 70 percent of U.S. power generation.[59]

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.[60]

58 DOE, *AER 2009*, Table 8.2a.
59 *Id.*
60 Electric Power Research Institute (EPRI), Natural Resources Defense Council & Charles Clark Group, *Environmental Assessment of Plug-In Hybrid Electric Vehicles: Volume 1: Nationwide Greenhouse Gas Emissions* (2007).

FIGURE P16

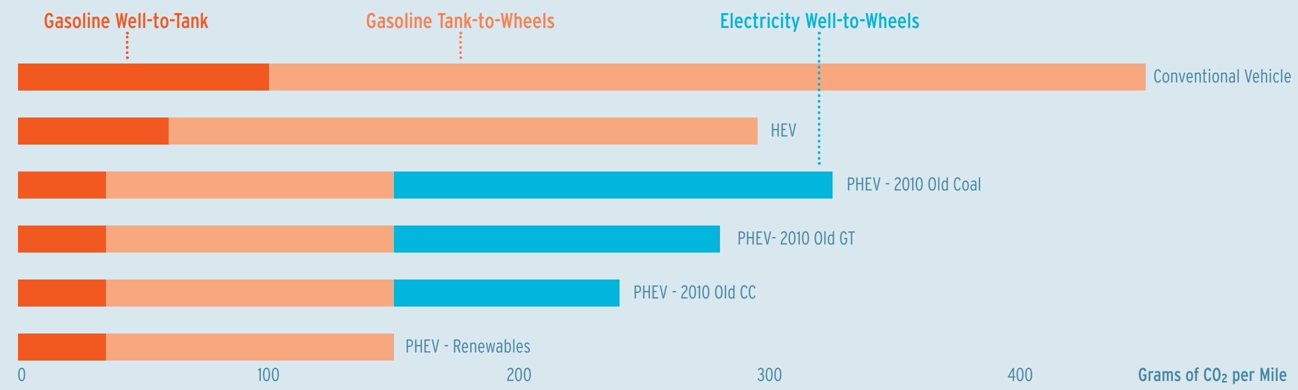
Relative Efficiency of Sample Light-Duty Vehicle Technologies



Notes: 1. EV efficiecny assumes electricity generated from natural gas at the U.S. national average heat rate of 8,305 Btu/kWh; 10 percent line loss; and motor efficiency of 4.0 mi/kWh 2. Full hybird mpg assumed at 50 3. ICE mpg assumed at 30 4. NGV mpg-e assumed at 28 5. Gaoline assumed at $3/gal; CNG at $1.50 GGE; electricity at $0.10/kWh.

FIGURE P17

Vehicle Emissions by Technology and Fuel



Source: Electric Power Research Institute; Natural Resources Defense Council

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.[61] Natural gas is low cost and easily dispatchable.

As a fuel, natural gas contains about 30 percent less CO_2 than oil and 45 percent less than coal on an energy equivalent basis.[62] 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.[63] 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.[64] Current-generation combined cycle plants reach efficiency levels of 60 percent,[65] 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.[66]

One recent study from the Oak Ridge National Laboratory simulated the impact of significant adoption of PHEVs throughout the United States.[67] The study assumed that more than 19 million PHEVs would be on the road by 2020, and it plotted penetration across different National Electricity 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.

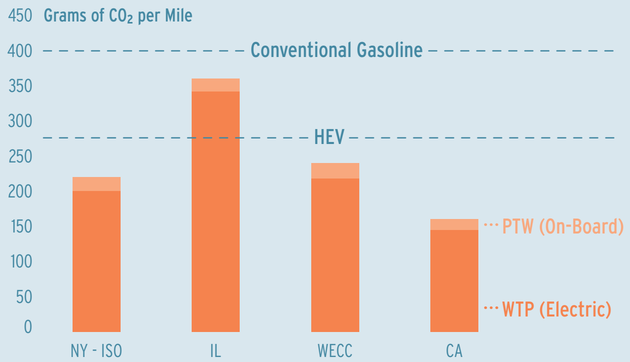
Most recently, Argonne National Laboratory simulated the well-to-wheels emissions profile of a number of PHEVs with varying battery sizes in different regions of the United States.[68] The analysis found that a PHEV-40 in charge-depleting (CD) mode had significantly lower CO_2 emissions than a conventional 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 emission 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 51 percent utility factor for a PHEV-40, which is conservative).

Energy Security: Electric drive systems represent a substantial improvement from an energy security

61 Oak Ridge National Laboratory (ORNL), *Potential Impacts of Plug-in Hybrid Electric Vehicles on Regional Power Generation* (2008), available at http://apps.ornl.gov/~pts/prod/pubs/ldoc7922_regional_phev_analysis.pdf.
62 DOE, EIA, Natural Gas Issues and Trends, at 58 (Table 2) (1999).
63 János M.Beér, "Higher Efficiency Power Generation Reduces Emissions: National Coal Council Issue Paper, at 2 (2009).
64 DOE, EIA, *Electric Power Annual 2009 (EPA 2009)*, Average Operating Heat Rate for Selected Energy Sources, available at http://www.eia.doe.gov/cneaf/electricity/epa/epat5p3.html.
65 GE Energy, "Gas Turbine and Combined Cycle Products," at 4, available at www.gepower.com/prod_serv/products/gas_turbines_cc/en/downloads/gasturbine_cc_products.pdf, last accessed on August 28, 2009.
66 Authors' calculations assuming natural gas contains 45 percent less carbon than coal, and comparing a combined cycle gas turbine (60 percent efficiency) to the existing coal fleet (32 percent efficiency).
67 ORNL, *Potential Impacts of Plug-in Hybrid Electric Vehicles on Regional Power Generation* (2008).
68 Argonne National Laboratory, *Well to Wheels Analysis of Energy Use and Greenhouse Gas Emissions in Plug-in Hybrid Electric Vehicles* (2010).

FIGURE P18

Well-to-Wheels Emissions: PHEV-40 in CD Mode



WTP = Well-to-Pump; PTW = Pump-to-Wheels; CD = Charge Depleting; CS = Charge Sustaining

FIGURE P19

Well-to-Wheels Petroleum Use

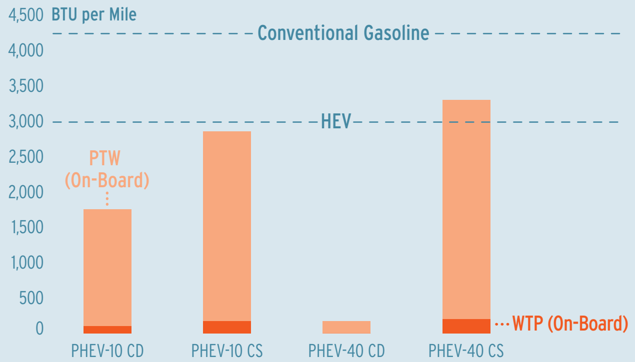
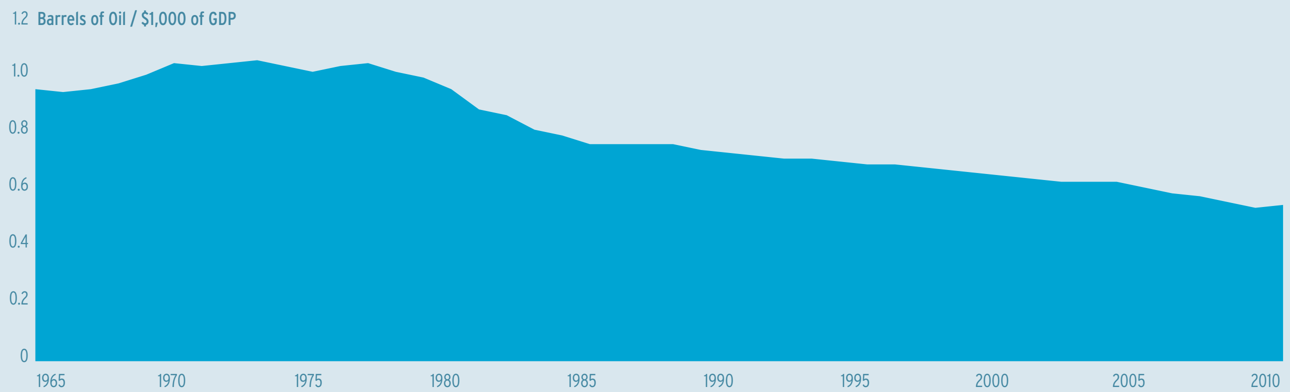


FIGURE P20

Oil Intensity of the U.S. Economy (Real $2005)



Sources: Figure P18, P19 — Argonne National Laboratory; Figure P20 — U.S. Bureau of Economic Analysis; BP, plc., *Statistical Review of World Energy 2010*

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.[69] 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.[70] 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 advancement 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.

69 *Id.*
70 BP plc, *Statistical Review of World Energy 2010*, at 11; U.S. Bureau of Economic Analysis; and SAFE analysis.

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 CO_2 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.[71]

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.

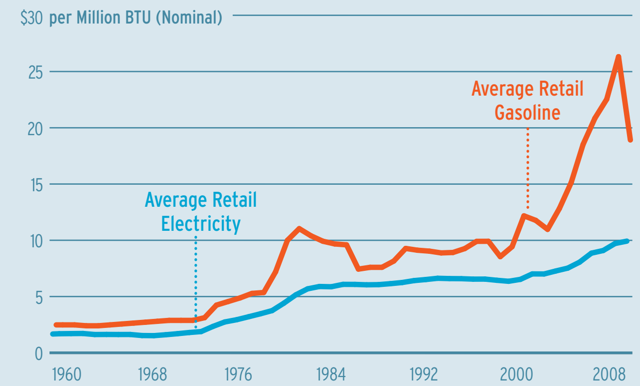
In addition to this diversity of supply, the fuels used to generate electricity are generally sourced domestically. All renewable energy is generated using domestic resources. The United States is a net exporter of coal. In 2009, only 12 percent of natural gas demand was met by imports, and approximately 90 percent of these imports were from North American sources (Canada and Mexico).[72] 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.[73]

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 1983, the average nominal retail price of electricity delivered in the United States has risen by an average of less than 2 percent per year in nominal terms and has actually

71 DOE, *AER*, Table 8.2a.
72 DOE, *AER*, Table 6.3.
73 DOE, EIA, 2008 Uranium Marketing Annual Report (UMAR 2009) p. 1 (2009).

FIGURE P21

Retail Electricity & Gasoline Prices



Source: DOE, *AER 2010;* EC Analysis

fallen in real terms.[74] Moreover, nominal prices have risen by more than 5 percent year-over-year only three times in that time period.[75] 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 the fuel. The remaining costs are largely fixed.[76] 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.[77] 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.[78] 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

74 DOE, *AER 2009*, Table 8.10.
75 *Id.*
76 DOE, EIA, *"Energy in Brief-What Everyone Should Know: How is my Electricity Generated, Delivered, and Priced?"* available at http://tonto.eia.doe.gov/energyexplained/index.cfm?page=electricity_in_the_united_states.
77 DOE, EIA, *"Gasoline Explained: Factors Gasoline Prices"* available at http://tonto.eia.doe.gov/energyexplained/index.cfm?page=gasoline_factors_affecting_prices.
78 DOE, *EPA 2007*, Table 4.5; DOE, *UMAR 2009*, Table S.1.b; DOE, *AER 2008*, Table 8.10.

FIGURE P22

Nymex Settlement Price

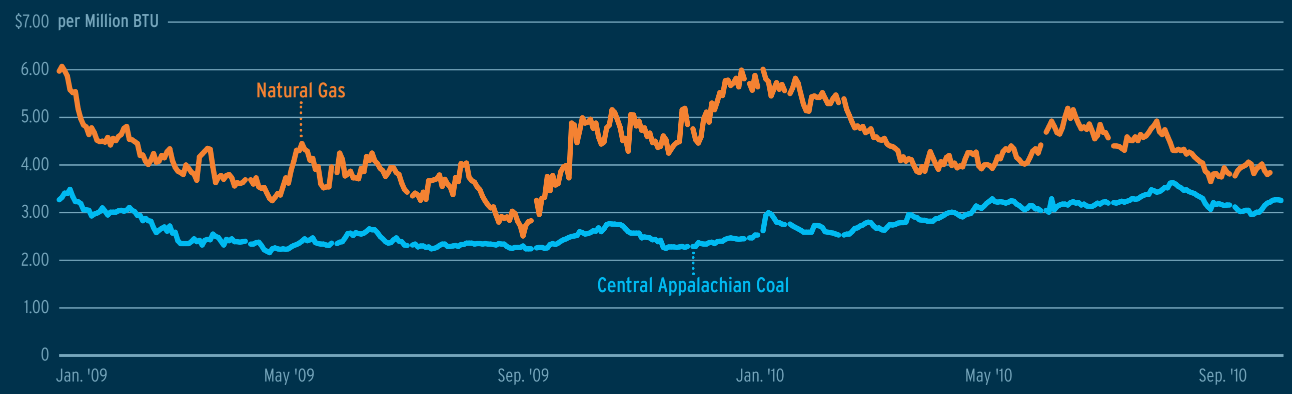


FIGURE P23

U.S. Proved Reserves, Dry Natural Gas

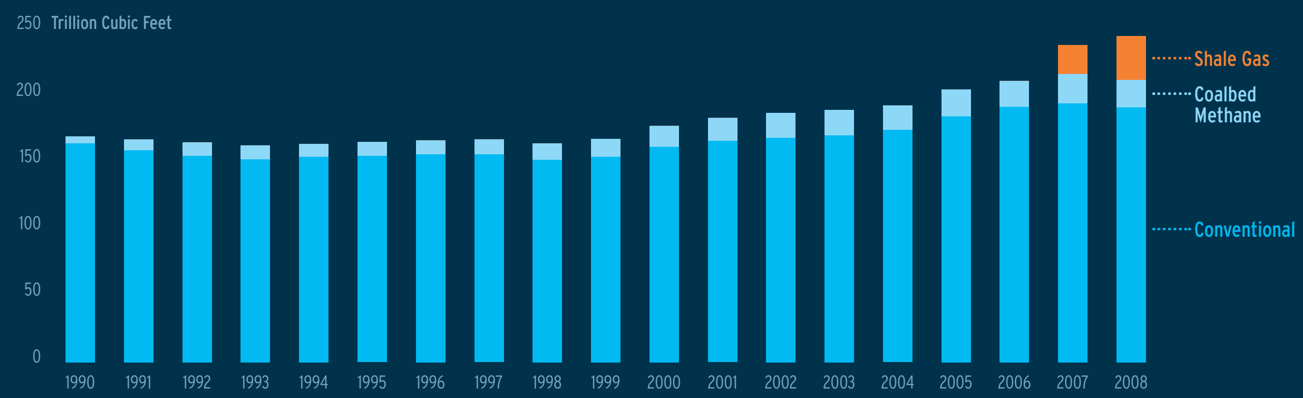
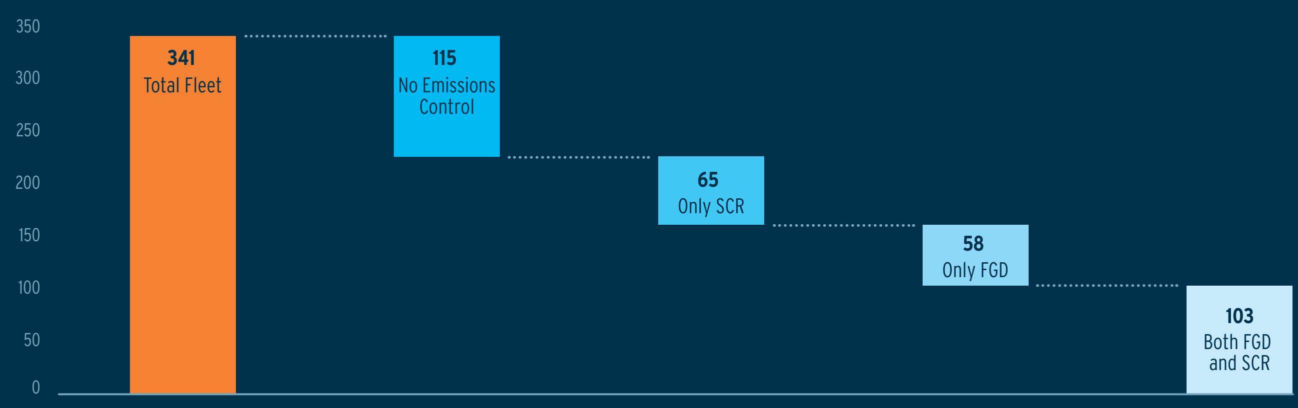


FIGURE P24

U.S. Coal Power Plant Capacity (GWh)



Source: Figure P22 – DOE, EIA; EC Analysis; Figure P23 – DOE, EIA; Figure P24 – Credit Suisse

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 retail 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 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 plugging 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 that was a 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.[79] 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 $6.00 per million Btu.[80] 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.[81]

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 a 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 desulphurization (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.

79 BP, plc, *Statistical Review of World Energy 2010*, at 22.
80 Credit Suisse, *The Impact of Shale Gas*, at 36, (September 24, 2010).
81 *Id.*, at 33.

A Growth Sector for Jobs

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.[82] In short, while the Great Recession officially ended in 2009, many Americans are still waiting to feel the recovery.

Though 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.[83] And while only 1 in 10 Americans are currently employed in manufacturing, the erosion of the domestic industrial base has clearly stunted efforts to stimulate aggregate job creation.[84]

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.[85] The ascendency 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.[86] 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.[87]

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.[88] As oil prices steadily rose throughout 2008, sales plummeted, falling 20 percent off their 2007 mark.[89] 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.[90] 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.[91]

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.[92]

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 research and development and standardization efforts.[93] 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.[94] 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 investment is being allocated to support the industry. A comprehensive approach to supporting early demand for grid-enabled vehicles will help capitalize on these investments.

82 International Monetary Fund, *World Economic Outlook 2010*, Table 2.2, at 70.
83 U.S. Department of Labor, Bureau of Labor Statistics, *U.S. Employment Situation*, Table B-1 (October 6, 2010), available at http://www.bls.gov/news.release/empsit.toc.htm.
84 *Id.*
85 United Nations, Industrial Statistics, available at http://unstats.un.org/unsd/industry/default.asp.
86 Ward's Automotive Group, *Ward's Motor Vehicle Facts and Figures 2010*.
87 *Id.*
88 Motor Intelligence, available at http://www.motorintelligence.com/.
89 *Id.*
90 *Id.*
91 DOE, ORNL, *TEDB 2009*, Table 10.18.
92 Thomas Grillo, "A123 opens Michigan plant," Boston Herald, September 24, 2010; Sebastian Blanco, "EnerDel shows off battery production facility, plans for $237 million expansion," Autoblog, January 22, 2010; Carl Apple, "How do I Land a Battery Plant Job?" February 24, 2010.
93 David Barboza, "China to Invest Billions in Electric and Hybrid Cars," New York Times, August 19, 2010.
94 Owen Fletcher, "China Ministry: Government Has Consensus To Promote Electric Cars," Dow Jones Newswire, October 28, 2010.

FIGURE P25
U.S. Unemployment Rate

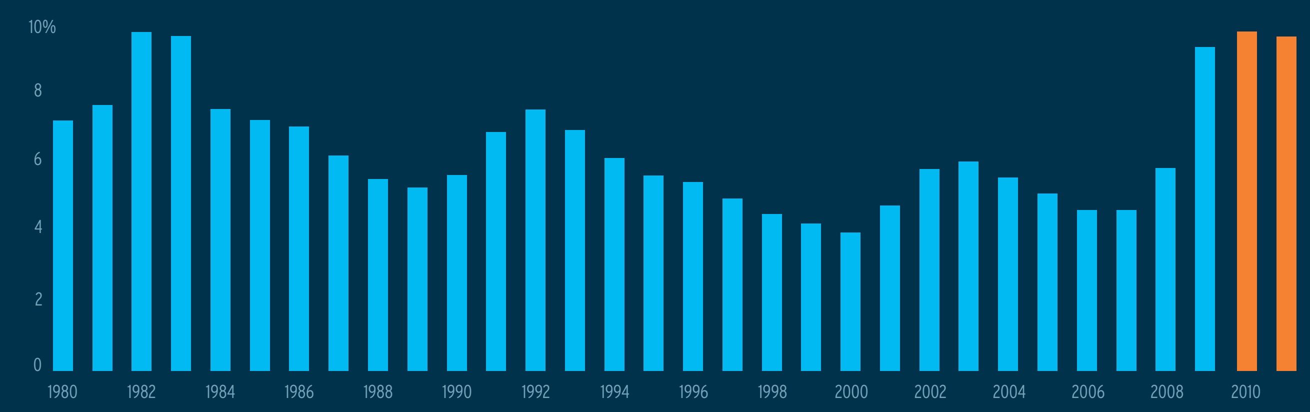


FIGURE P26
Share of Global Manufacturing Output

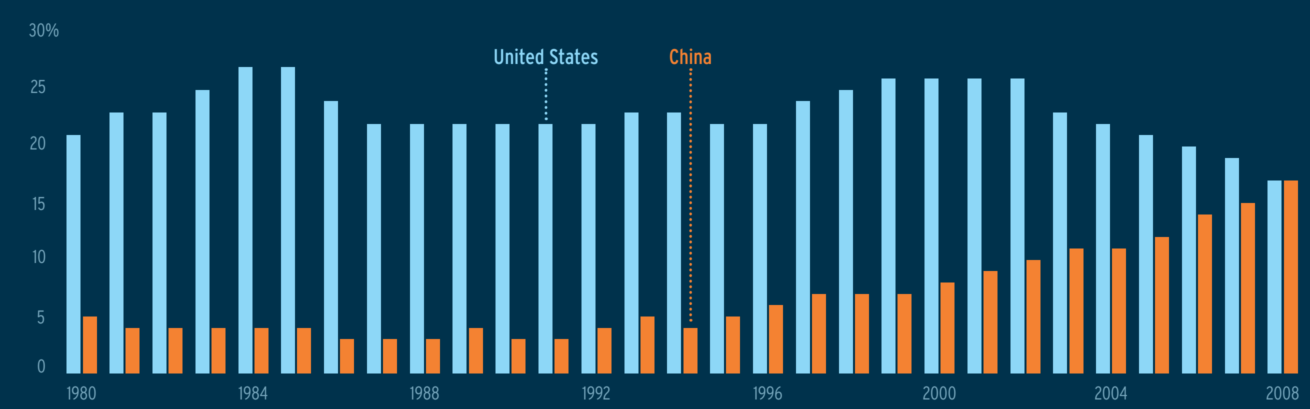
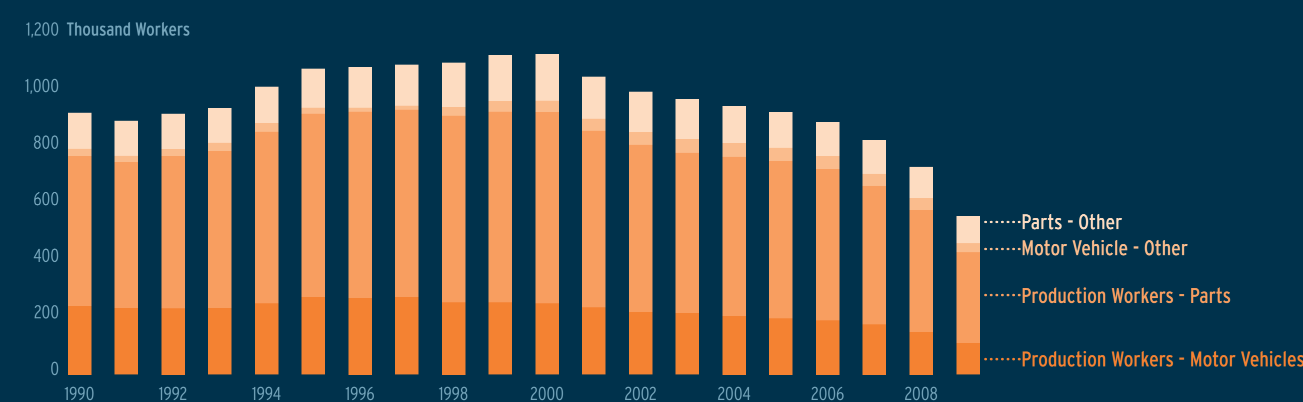


FIGURE P27
U.S. Vehicle Manufacturing Employment



Source: Figure P25 – International Monetary Fund, *World Economic Outlook 2010*; Figure P26 – United Nations Statistics; Figure P27 – DOE, ORNL, TEDB Ed. 29

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 automakers 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 GEVs is nonetheless impressive.

Still, a number of technological and economic challenges remain to be addressed before electric drive technologies 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 of 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.[95] 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.[96] 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.[97] 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.[98]

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 cancelled or postponed, significantly setting back the industry in the United States compared to its competitors abroad.

95 Consumer Reports, "Electric Nissan Leaf sold out with pre-orders," May 26, 2010.

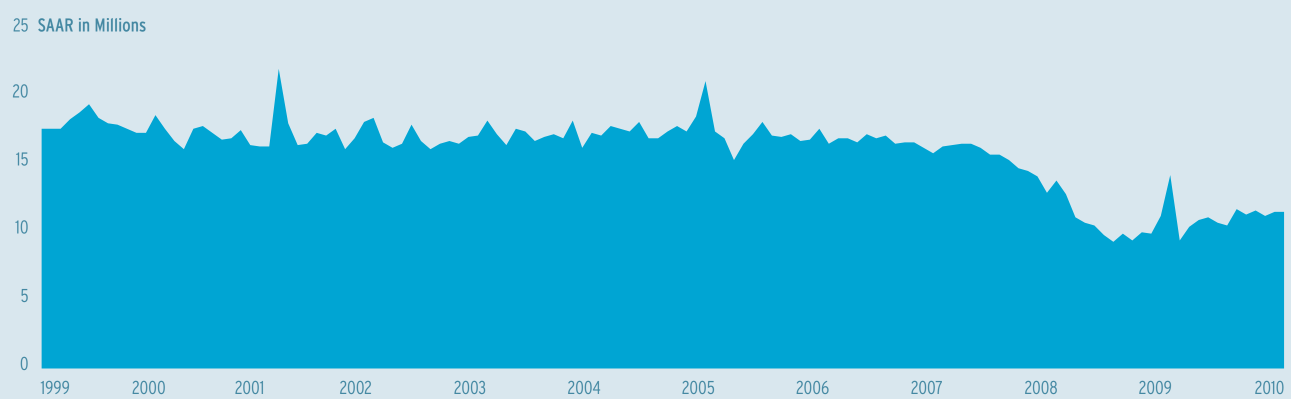
96 David Shepardson, "GM Exec Predicts 60,000 Volt Models Built in 2012," Detroit News, October 15, 2010.

97 DOE, *AEO 2010*, online supplemental Table 58.

98 *Id.*, Tables 57 and 58.

FIGURE P28

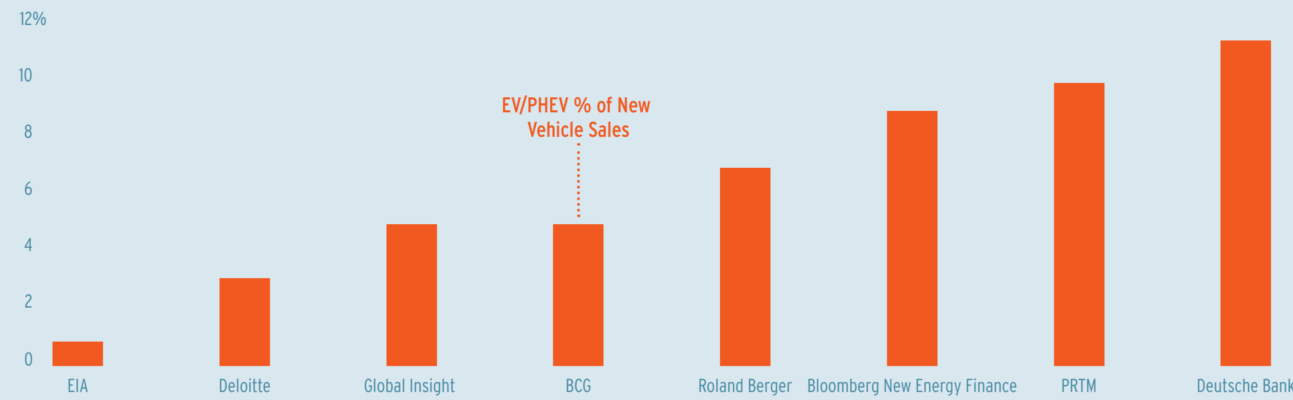
Total Monthly Annualized Auto and Light Truck Sales



Source: Motor Intelligence

FIGURE P29

Median Forecast, U.S. PHEV and EV Sales Share (2020)



Source: EC Analysis

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.[99] 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 as 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.

99 DOE, *AEO 2010*, Table A-7.

A New York Times Dodge Sprinter plug-in hybrid electric vehicle (PHEV), which will be used for newspaper delivery, is seen April 11, 2007 in New York City. The vehicle is the first medium-duty plug-in hybrid vehicle on the East Coast and can operate up to 20 miles in zero-emission electric mode or as a hybrid with a diesel.

FIGURE P30

U.S. Oil Demand By Sector

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. Electrified 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, electrified 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.

Based on total cost of ownership modeling conducted for his report, commercial and government fleets could contribute substantial volume commitments in the early development phases of the GEV market.

PART ONE

The Case for 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.[1] While the size of individual fleets varies significantly, the top 50 fleet operators together manage more than half a million vehicles.[2]

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 manage 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 financing strategies and cost considerations. In 2009, 80 percent of the fleet cars and class 1-5 trucks on the road in the United States were privately owned; 20 percent were leased.[3] The top 10 fleet leasing companies own and operate nearly 3 million vehicles in total.[4]

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 their operators more likely than typical consumers to take on the potential risks of electric drive vehicles.

The most significant challenges facing consumer adoption of electric vehicles today are the high upfront cost of the vehicles themselves—a cost driven largely by batteries—and the absence of publicly available refueling 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 charge 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.

1 PRTM analysis; This figure is derived from a composite of data sources, including R.L. Polk, Automotive Fleet, U.S. General Services Administration, GE Capital, Utilimarc, and others.

2 Bobit Publishing Company, *2010 Automotive Fleet Factbook (AFB)*, available at http://www.automotive-fleet.com/Statistics/

3 *Id.* at 9.

4 *Id.* at 44.

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.[5, 6] In 2009, there were approximately 4.8 million automobiles and 4.3 million class 1-2 light trucks in operation in fleet applications. 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 1A for a breakdown of vehicle class by weight.)

5 The legal definitions that distinguish passenger cars from light-weight light duty trucks can be found at 49 CFR 523 (2010).

6 Gross vehicle weight is defined as maximum allowable total mass of a road vehicle or trailer when loaded. Trucks are segmented from class 1 through 8 and delineated strictly by gross vehicle weight. The truck classification system is based on the U.S. Department of Transportation classification system.

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.

FIGURE 1A

Vehicle Class by Weight

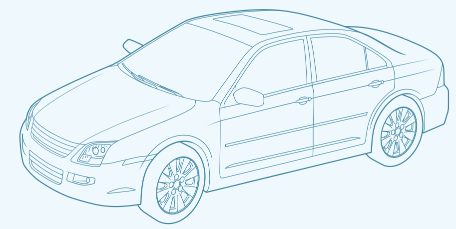
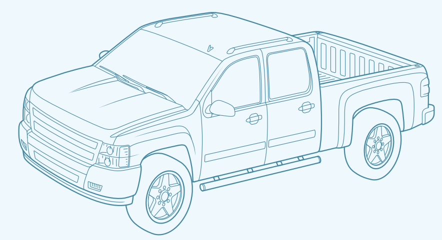
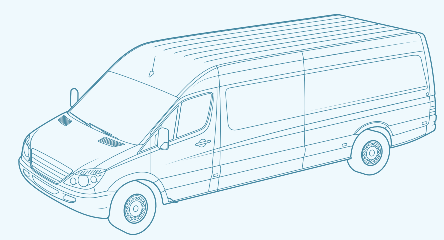
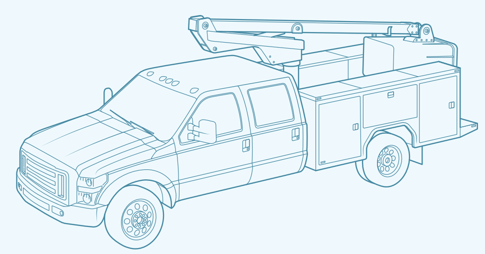
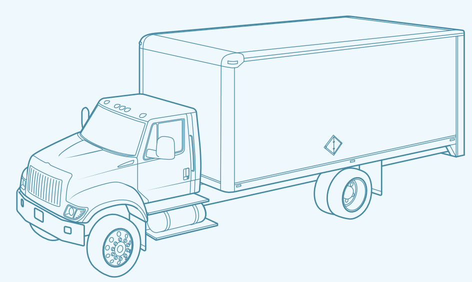
EXAMPLE	GROUP	CLASS	COMMON EXAMPLES	GROSS VEHICLE WEIGHT
	Auto	Class 1	Ford Focus Nissan Altima	< 6,000 lbs
	Light-Duty Trucks	Class 1	Ford Ranger GMC Canyon	< 6,000 lbs
		Class 2	Dodge Ram Ford F-150	6,001-10,000 lbs
	Medium-Duty Trucks	Class 3	Ford F-350 GMC Sierra 3500	10,001-14,000 lbs
		Class 4	Ford F-450 GMC Sierra 4500	14,001-16,000 lbs
		Class 5	Ford F-550 GMC Sierra 5500	16,001-19,500 lbs
		Class 6	Ford F-650 GMC Topkick International Durastar	19,501-26,000 lbs
	Heavy-Duty Trucks	Class 7	International Transstar	26,001-33,000 lbs
		Class 8	Tractor Trailor	> 33,000 lbs

FIGURE 1B

Vehicles In Operation by Sector & Application

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.

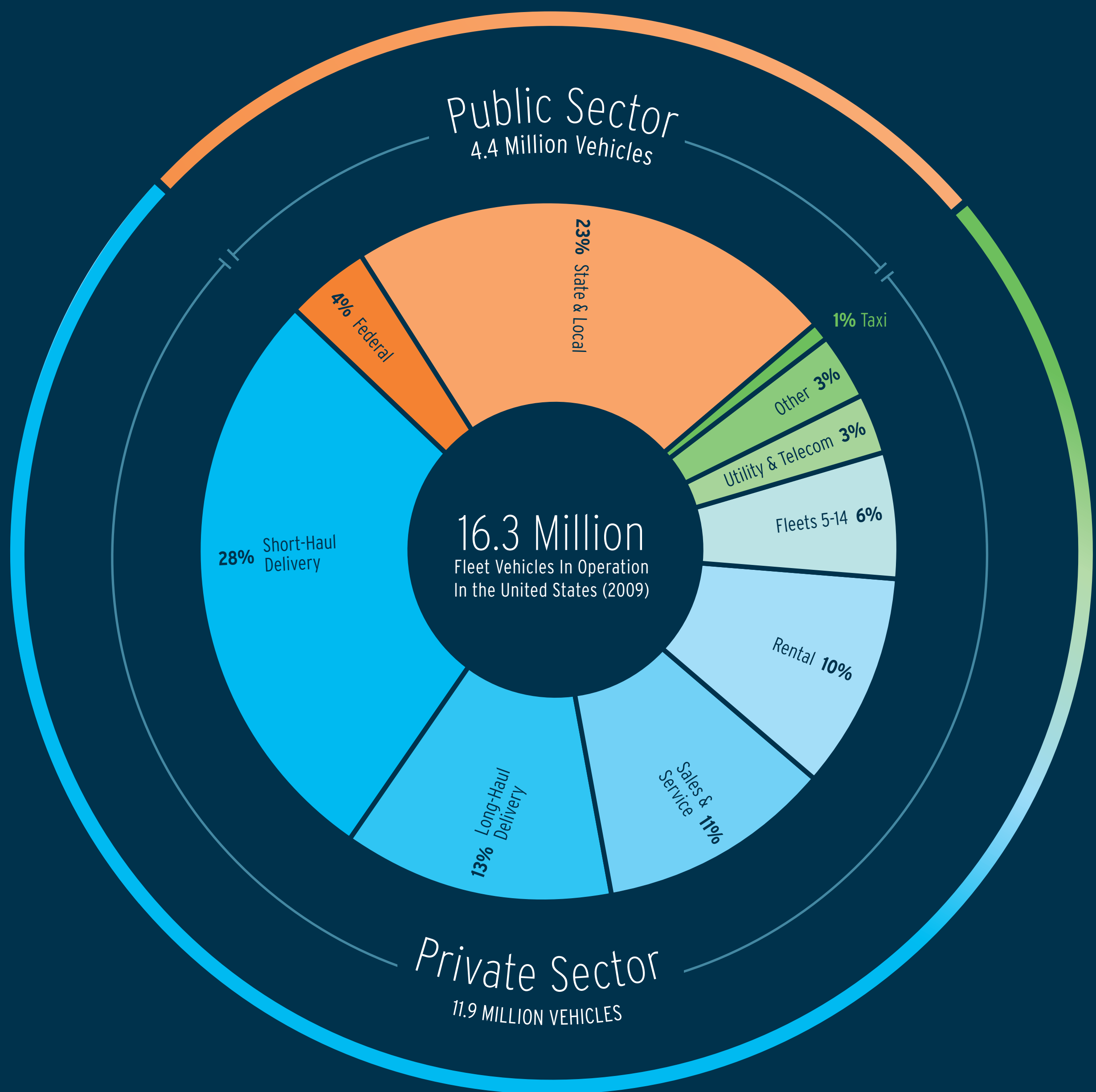
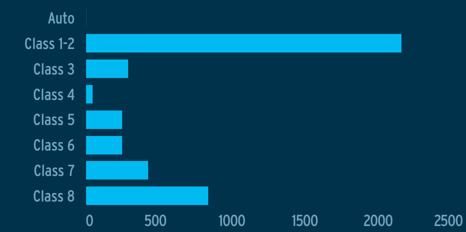


FIGURE 1C

Vehicles In Operation by Application & Class

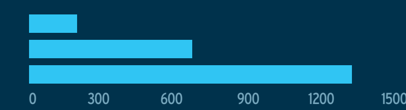
NOTE: Vehicle Applications are listed in order of market share; vehicle class domains vary in scale and are measured in thousands.

Short-Haul Delivery / 4.5 Million



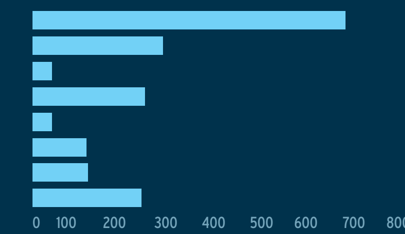
Short-haul delivery vehicles made up one of the largest fleet segments in the United States in 2009, totaling 4.5 million vehicles in operation across all vehicle classes. The size of the short-haul delivery asset class is heavily skewed toward lighter trucks and cargo vans. Nearly 50 percent of vehicles in operation are class 1 and 2 trucks.

Long-Haul Delivery / 2.1 Million



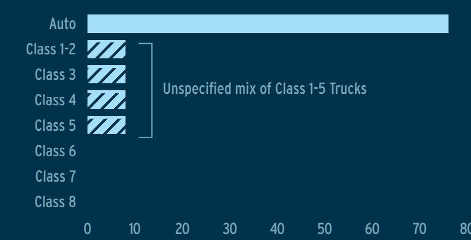
There were more than 2 million long-haul freight vehicles in fleet applications in operation in the United States in 2009. The size of the asset class is generally class 6 and higher, and class 8 vehicles account for more than half of the total. Class 8 vehicles include combination tractor trailers as well as other applications.

Sales & Service / 1.7 Million



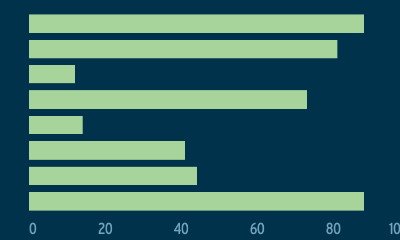
Sales and service vehicles totaled 1.7 million in 2009. The size of the asset class is somewhat skewed toward the lighter end of the spectrum, with nearly 1 million autos and class 1-3 trucks in operation. Typical sales and service vehicles range from light-duty passenger car fleets in the pharmaceutical industry up to class 8 refuse removal trucks.

Rental / 1.6 Million



There were approximately 1.6 million rental fleet vehicles in operation in 2009. The majority–76 percent– were automobiles. The rest were a mix of class 1-5 trucks. Originally more focused on longer trips like vacations, the rental industry has expanded to meet the needs of predominantly urban consumers who do not own vehicles but may need to use one on occasion. Car sharing services are a good example of one such new model.

Utility & Telecom / 500,000



There were nearly half a million vehicles in operation in utility and telecom fleets in 2009. The size of the asset class is somewhat evenly distributed across vehicle classes, though the light and heavy ends of the spectrum are most prominent. Typical utility and telecom vehicles range from light-duty cars and trucks used for reading meters and making routine customer visits to heavier trucks used to maintain and repair damaged infrastructure.

Other / 450,000

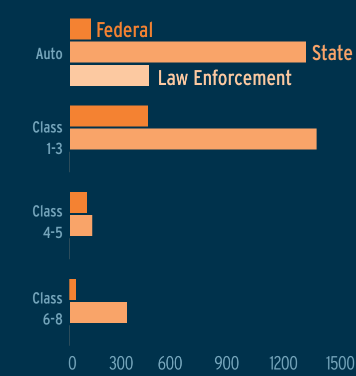
Other vehicles include privately owned and operated school buses among other vehicles. In 2009, there were approximately 450,000 privately owned and operated heavy-duty school buses in the United States.

Fleets 5 - 14 / 960,000

Class one automobiles in fleets with between 5 and 14 vehicles totaled 960,000 across multiple industries in 2009. More detailed data is generally not available.

Taxi / 150,000

There were more than 150,000 vehicles operating as part of taxi fleets in the United States in 2009. Essentially 100 percent of these vehicles are passenger automobiles and minivans or SUVs, though cars account for the majority.



State & Local / 3.7 Million

State and local governments maintain 3.7 million fleet vehicles in operation, including law enforcement vehicles. More than two-thirds of state and local government vehicles are autos or class 1-2 light-duty trucks. More than 10 percent are transit and other buses operated by municipal and regional transit authorities.

Federal Vehicles / 650,000

There were approximately 650,000 federal fleet vehicles in operation in 2009, operated by nearly 40 civilian agencies and the Department of Defense. Civilian agencies accounted for 36.9 percent of the total, military agencies for 29.9 percent, and the U.S. Postal Service alone accounted for the balance–33.2 percent. Postal light-duty trucks of less than 8,500 pounds GVW accounted for 29.8 percent of all federal fleet vehicles. Nearly two-thirds of the federal fleet is class 1-3 trucks.

CHAPTER 1.3

Advantages of Fleet Operators

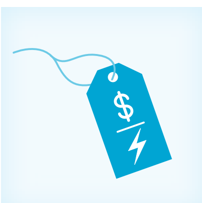
Commercial and government fleets possess a number of key advantages that could enable them to be early adopters of grid-enabled vehicles. These advantages include the way fleet managers make vehicle acquisition decisions as well as certain unique operational traits of fleets.

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 for most fleet operators than it is for typical consumers.

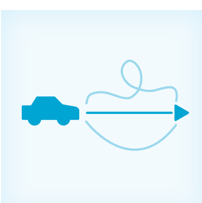
While consumers often focus on vehicle aesthetics, performance, and style, most fleet operators focus heavily on the life-cycle economics of an acquisition. The lower operating and maintenance costs of PHEVs and EVs should provide clear value to fleet owners, particularly in higher mileage applications and in cases where upfront costs can be offset through battery right-sizing, extended ownership periods, light-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.



Total Cost of Ownership Approach to Acquisition

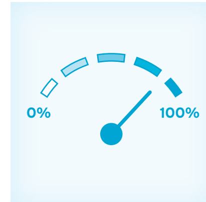
When asked, fleet managers rank total cost of vehicle ownership as the most significant factor driving acquisition decisions.[7] Consumers, on the other hand, may purchase for a variety of reasons, including aesthetics and style, in addition to cost. If electric drive technologies can be proven to reduce 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 light-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.

7 EC, PRTM interviews.
8 PRTM analysis.

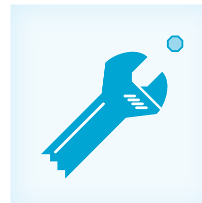


High Vehicle Utilization Rates

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.

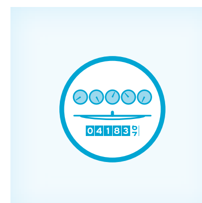
Use of Central Parking Facilities

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.



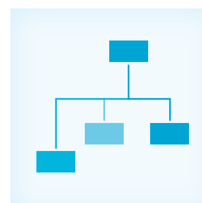
Importance of Maintenance and Service Costs

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.



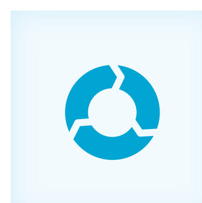
Lower Electricity Rates

The electricity rates paid by commercial and industrial consumers—those most likely to make use of 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, 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 owners 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, 63 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.[9] Just 18 percent of respondents indicated that the basic purchase price was the main factor.[10] Within total cost, the survey found that fleet operators rank acquisition cost as their first priority most often, fuel economy or fuel costs as their second priority, and other operating costs as their third priority.[11]

Understanding TCO

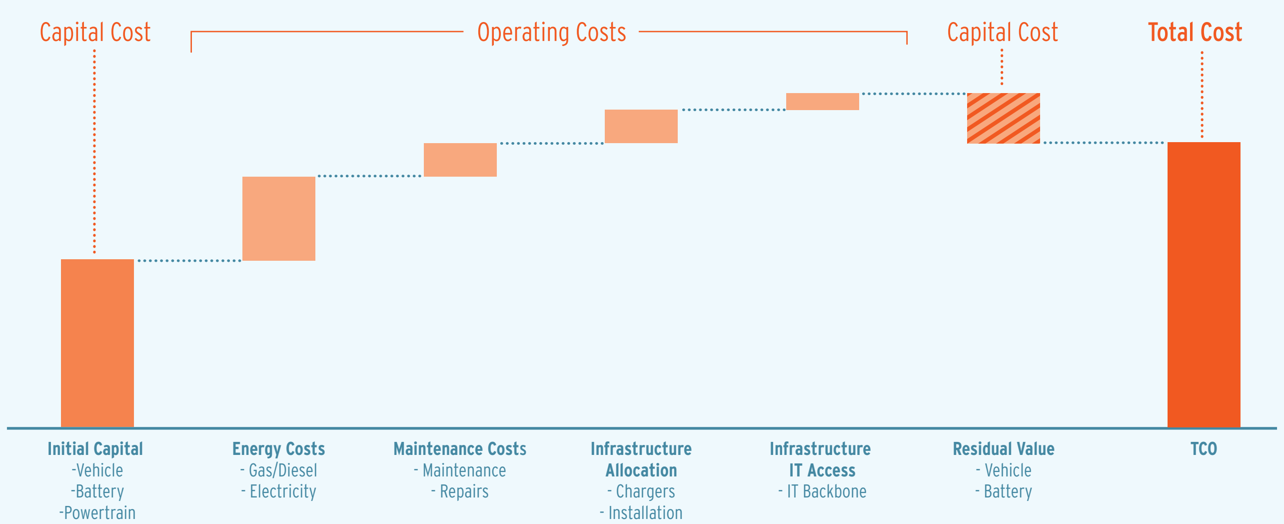
A vehicle's total cost of ownership represents the sum of the capital and operating costs associated with ownership. In other words, TCO equals the fully-burdened cost of purchasing, refueling, and maintaining a vehicle over the entire ownership period. For gasoline- and diesel-powered vehicles, TCO 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 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:

9 Frost and Sullivan, "Strategic Analysis of the North American and European Electric Truck, Van and Bus Markets" (2010).
10 *Id.*
11 *Id.*

FIGURE 1D
Illustrative Total Cost of Ownership: Traditional Ownership



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.

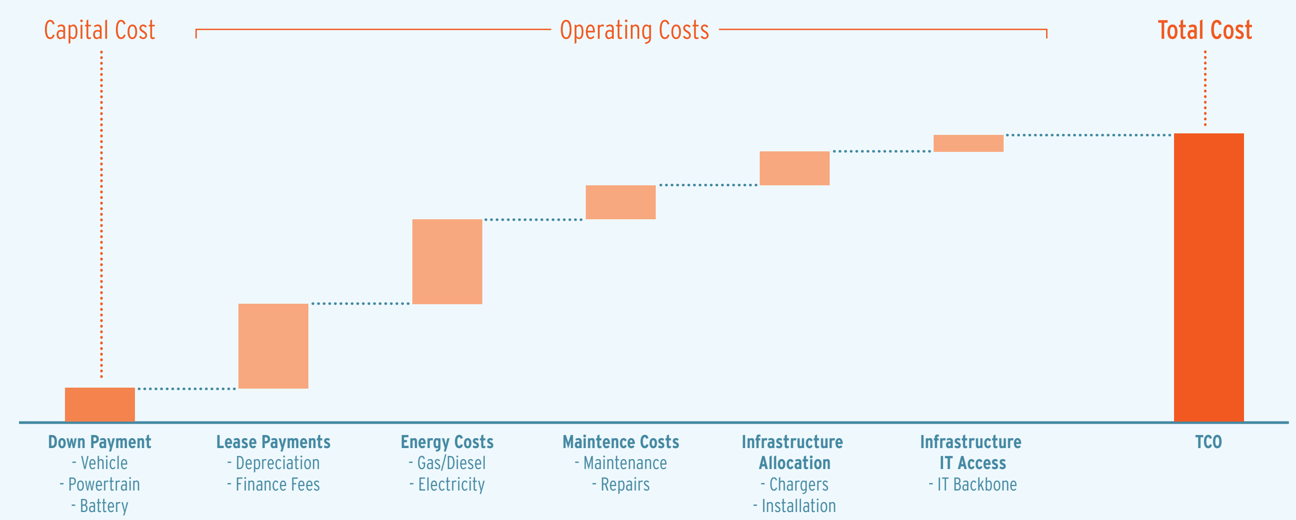
Ownership Structure and TCO

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.[12] 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.[13] The 10 largest fleet lessors managed nearly 3 million cars and trucks in U.S. fleets in 2009.[14]

12 Bobit Publishing Company, *AFB 2010*, at 9.
13 *Id.*
14 *Id.* at 44

FIGURE 1E
Illustrative Total Cost of Ownership: Closed-end Lease



Route Predictability

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.[15] 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.[16]

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.[17] 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 opportunities to charge these vehicles may be available in public, the degree of over-specification is even starker: more than 90 percent of individual trips are less than 30 miles.[18]

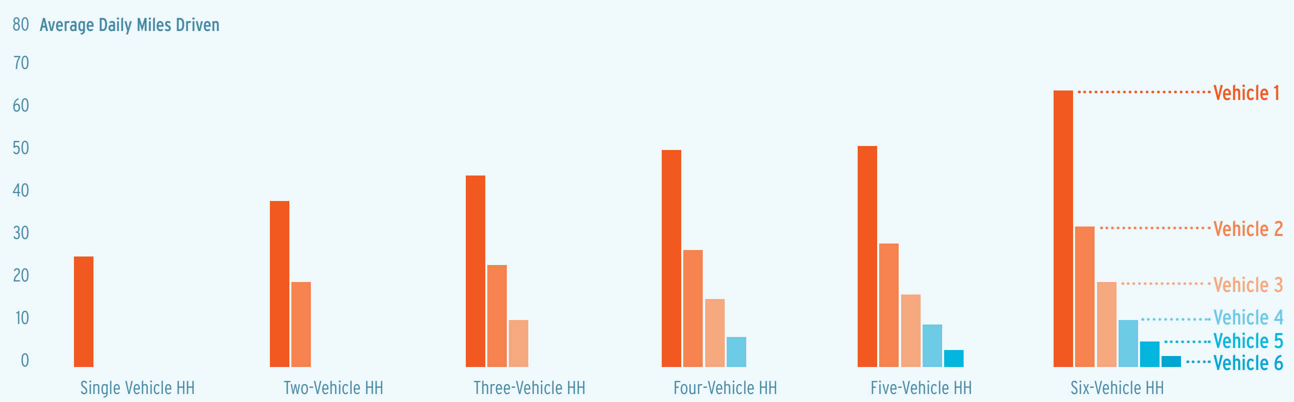
Part of the rationale for extra battery capacity is that consumers will be uncomfortable with the limited electric drive range of PHEVs and EVs compared to their petroleum-fired vehicles. As a result, they may hesitate to purchase PHEVs and EVs in the absence of an abundance of excess range—so-called range anxiety. Much more important is 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[19] (See Figure 1G). This premium will reduce the economic attractiveness of the first generation of EVs and PHEVs for many consumers. Even though the operating and fuel costs of a GEV may be much lower over the life of the vehicle, the upfront capital costs associated with today's batteries are essentially prohibitive in the absence of government subsidies, with payback periods that can exceed 10 years. This dynamic could be particularly problematic in heavier applications that would require larger batteries for electric drive technologies.

15 DOE, ORNL, *TEDB 2009*, Figure 8.5.
16 *Id.* Table 8.14.
17 *Id.*
18 DOE, ORNL, *TEDB 2009*, Table 8.3.
19 PRTM analysis.

FIGURE 1F

Daily Miles Traveled for Each Vehicle in a Household



Source: DOE, ORNL, Transportation Energy Data Book

FIGURE 1G

Battery Cost as a Percent of Vehicle Price

DRIVETRAIN	CLASS	KWH	$/KWH	BATTERY COST	VEHICLE COST	BATTERY % OF VEHICLE COST
HEV	Auto	1.5	1,200	$1,800	$30,000	6
PHEV	Auto	12	660	$7,920	$36,000	22
EV	Auto	24	600	$14,400	$41,000	35
PHEV	Class 4-5	29	792	$22,900	$67,000	34
EV	Class 4-5	65	720	$46,800	$92,000	51

Source: Interviews, Published Vehicle Specs, PRTM Estimates

In contrast, fleets may have the ability to 'right-size' batteries for a given mission, thereby reducing upfront vehicle costs. This ability stems from the fact that the predictability of routes traveled by fleet vehicles is particularly high in some industries and within certain companies and government institutions. In applications such as an urban product delivery fleet with a finite customer base, individual vehicle travel patterns can be highly routinized. For example, a bakery delivery truck driver might 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.

Because the first generation of lithium-ion batteries will represent such a large portion of overall vehicle cost, significant savings in this area could have a meaningful impact on vehicle economics and possibly on fleet purchase decisions. For example, optimizing the battery in a class 5 truck EV to provide 50 miles of range instead of 100 miles of range would reduce total upfront vehicle costs by nearly 20 percent. This kind of optimization might not be attractive to customers in the personal-use passenger vehicle space who will always want to be prepared for longer (infrequent) trips, but for fleets with high route predictability, optimization represents an opportunity to substantially reduce upfront costs and improve total cost economics for grid-enabled vehicles.

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 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.

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 in order to 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 7,300 and 12,800 miles per year, depending on the age of the vehicles themselves.[20]

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.[21] The average was closer to 23,000 miles for passenger cars.

Ultimately, however, high utilization rates present both opportunities and challenges for electric drive 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.

Taxis are good examples of high utilization fleets. In certain environments—particularly dense urban areas and cities with a high taxi registration fee—individual taxis are on the road between 16 and 24 hours per day.[22] The typical taxi in New York City logs as much as 100,000 miles per year.[23] As a result, taxis would be unlikely adopters of pure battery electric vehicles in the absence of a specialized charging solution, such as fast charging or battery swapping. Better Place, an end-to-end provider of vehicle infrastructure network solutions, is currently piloting a small fleet of taxis using swappable batteries in Tokyo, and recently expanded the project to San Francisco.[24]

20 DOE, ORNL, *TEDB 2009*, Table 8.9.
21 Bobit Publishing Company, *AFB 2009*.

22 Hai Yang, et al., "A macroscopic taxi model for passenger demand, taxi utilization and level of services," *Transportation*, 27: 317–340 (2000).
23 John Voelcker, "Cities Want High-Mileage Hybrid Taxis; Judge Says It's Illegal," Green Car Reports.com, July 29, 2010.
24 Jim Motavalli, "Better Place's Tokyo Battery Swap: A Test to Show the World," BNET, April 27, 2010.

FIGURE 1H

Average Annual Miles of Travel for Household Vehicles by Age

VEHICLE AGE	ANNUAL MILES TRAVELED (2009)
Less than 1 Year	12,800
1 Year	13,800
2 Years	13,500
3 Years	12,500
4 Years	11,800
5 Years	11,700
6 Years	11,300
7 Years	11,000
8 Years	10,300
9 Years	9,900
10 Years and Older	7,300
Average of All Household Vehicles	10,100

Source: DEO, ORNL, *Transportation Energy Data Book*

FIGURE 1I

Average Annual Miles of Travel for Business Fleet Vehicles

BUSINESS FLEET VEHICLES	ANNUAL MILES TRAVELED (2008)
Compact Cars	23,148
Intermediate Cars	23,412
Light Trucks	28,020
Minivans	27,852
SUVs	22,968
Full-Size Vans	25,212

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 (EVSE). 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.[25]

Vehicle Replacement Cycle

Vehicle utilization and other factors ultimately feed into the rate at which a fleet replaces its vehicles. In general, fleets that have high utilization rates tend to have higher 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.[26] In contrast, compact cars averaged three years in service in business fleet applications while intermediate cars averaged 2.4 years.[27] Light trucks averaged slightly higher at 4.25 years.[28]

Conditions in the broader economy can have a significant impact on the average age of fleet vehicles. During the 2007-2009 recession, the average ending months in service of fleet vehicles in operation increased by as much as 10 percent in certain asset classes.[29] 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.[30] 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.

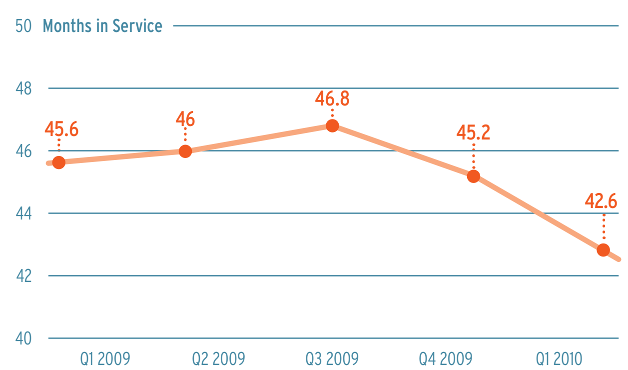
Rental companies are an example of a fleet industry segment that tends to have high turnover rates, making it a potentially attractive option for accelerating the deployment of electric drive technologies. Because the average rental fleet acquires new vehicles as often as every six to 10 months, the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

25 EC, PRTM interviews.
26 DOE, ORNL, *TEDB 2008*, Table 3.9.

27 DOE, ORNL, *TEDB 2009*, Table 7.2.
28 *Id.*
29 GE Capital, Fleet Services.
30 Scott Doggett, "Nissan Leaf Battery Warranty Same as Chevy Volt's - 8 Years or 100,000 Miles," Edmunds.com, July 27, 2010.

FIGURE 1J

Average Cycle, Fleet Cars and Light Trucks



Source: Bobit Publishing Company

FIGURE 1K

Average Ending Months in Service, Business Fleet Vehicles

VEHICLE TYPE	AVERAGE MONTHS IN SERVICE
Compact Cars	36
Intermediate Cars	29
Light Trucks	51
Minivans	36
SUVs	29
Full-Size Vans	56

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 space overnight. 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.[31] Some additional portion of private consumers may have access to permitted street parking or 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.[32] For homes that lack a dedicated parking space, the market has yet to determine how best to ensure access to overnight EVSE.

Important challenges will need to be addressed before home and workplace charging become prevalent, however. While drivers could in theory opt to charge their vehicles using the standard NEMA-approved 110 outlets found throughout the United States, most EV drivers will opt for the convenience of a Level II charger, which can reduce the charge time for a fully depleted EV battery to between three and seven hours, compared to

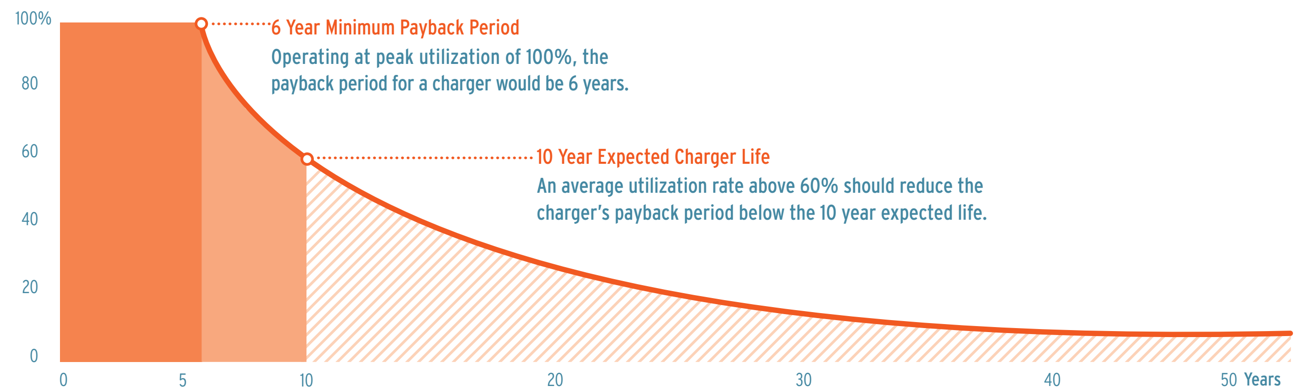
31 DOE, ORNL, *TEDB 2009*, Table 8.17.

32 California Energy Commission, *2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program*, at 39, (August 2010), available at http://www.energy.ca.gov/2010publications/CEC-600-2010-001/CEC-600-2010-001-CMF.PDF

FIGURE 1L
Charging Infrastructure: Terms of Service

CHARGER	APPLICATIONS	OUTLET STYLE	VOLTAGE	AMPERAGE	COST	EV CHARGE TIME	PHEV CHARGE TIME
Level One	Private	Standard U.S. Outlet	110v	12A	–	15-18 Hours	6-12 Hours
Level Two	Private / Public	Dryer or Large Appliance	220-240v	12-30A	$2K-$4K	3-7 Hours	1-3 hrs
Level Three	Private / Commercial	Industrial	440v		$15K-$50K	20 to 30 Min.	Not Applicable

FIGURE 1M
Expected Payback Period on Public Level II Charges



as long as 18 hours for a Level I charge. In addition, the rate of charging will be constrained by the capacity of the onboard vehicle charger, which is 3.3 kW for most light-duty GEVs today. A Level II charger at 15A would recharge a fully-depleted EV utilizing a 3.3 kW charger in six to seven hours.

Home installation of Level II charging will present drivers with an additional cost that will extend the payback period for EVs and PHEVs. Current cost estimates for Level II charging units range from $500 to $2,000 for the hardware alone.[33] The units currently qualify for a 50 percent tax credit that is scheduled to expire at the end of 2010 (as of publication, the credit has yet to be extended). Installation costs can add several thousand dollars to the cost of a Level II EVSE, and can be particularly expensive if panel upgrades or other electrical rewiring is required to support the 220v connection.[34] These are costs that must be borne by the consumer, and they can decrease the value proposition of purchasing an EV or PHEV in certain cases.

Public Charging

For most passenger market consumers, access to some amount of public charging infrastructure will be needed in the early stages of plug-in electric drive vehicle adoption. Significant uncertainty exists regarding the quantity and type of chargers needed, however. Some electric vehicle advocates have argued for deployment of a dense network of Level II chargers throughout urban areas in order to alleviate range anxiety, particularly for EV drivers. Others have suggested that the cost of deploying a wide network of Level II charging would be prohibitive, and that the need for pubic charging infrastructure is minimal assuming drivers have access to home and/or workplace charging as well as targeted opportunities to use fast charging technology.

Plug-in hybrid electric vehicles or extended-range electric vehicles add an additional layer of complexity to the infrastructure argument. In theory, such vehicles will require the absolute minimum amount of charging infrastructure—a home or workplace charger—because even in the event that the battery reaches a zero state of charge, the gasoline-powered engine provides the driver with practically unlimited range.

Nonetheless, nearly all drivers of grid-enabled electric vehicles—both EVs and PHEVs—will benefit from access to public charging. For drivers of all-electric vehicles, public charging will represent a practical necessity for trips that extend beyond the range of the battery, which could include a series of errands over the course of a busy Saturday. For PHEV drivers, there is likely to be a strong desire to maximize the number of electric miles traveled compared gasoline miles. If for no other reason, this will be because electricity-powered miles will be significantly less expensive than gasoline-fueled miles.

Business Models and System-wide Costs

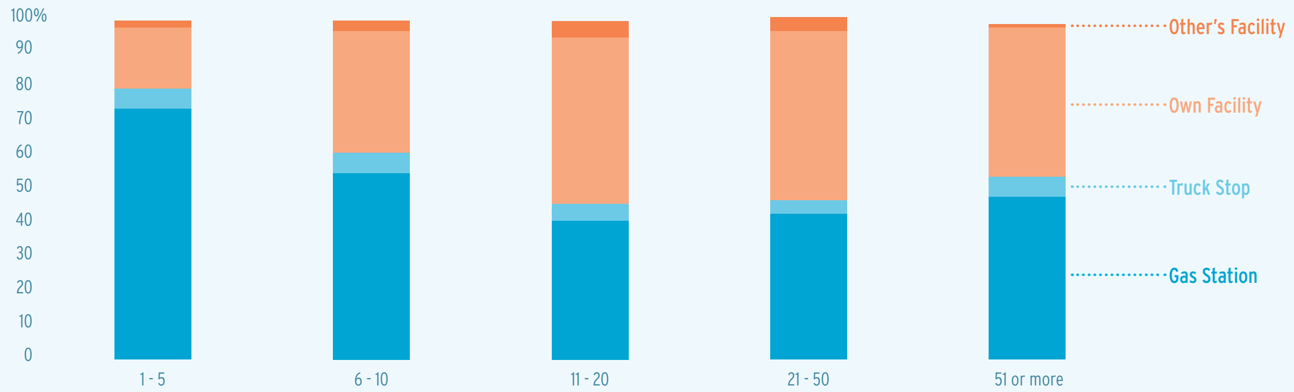
Perhaps the most significant challenges facing the deployment of public charging infrastructure will be business model and cost. Specifically, a profitable business model for public charging infrastructure has not been reliably demonstrated, and the ability of charger owners to recoup investment costs will depend on not only utilization, but whether they are able to collect a premium for charging. At odds with this, the consumer must recover the cost of

33 Jim Motavalli, "Home Charging for Electric Vehicle: Costs Will Vary," New York Times, March 16, 2010.

34 *Id.*

FIGURE 1N

Primary Fueling Option by Fleet Size



Source: DOE, ORNL, Transportation Energy Data Book

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 installed costs of $3,500, the payback period would be six years—but this assumes continuous (and unrealistic) use of the charge point. With utilization still at a generous 50 percent, plus the addition of operating costs, the payback period for public Level II chargers extends well beyond the expected 10-year life of the charger.

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.[35] 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.[36]

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.

35 U.S. Department of Commerce, Bureau of the Census, *2002 Vehicle Inventory and Use Survey.*

36 *Id.*

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.[37] 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.

37 EC calculations based on *Automotive Fleet* data.

FIGURE 1O

Maintenance and Service Costs as a Share of Operating Cost - ICE Vehicles

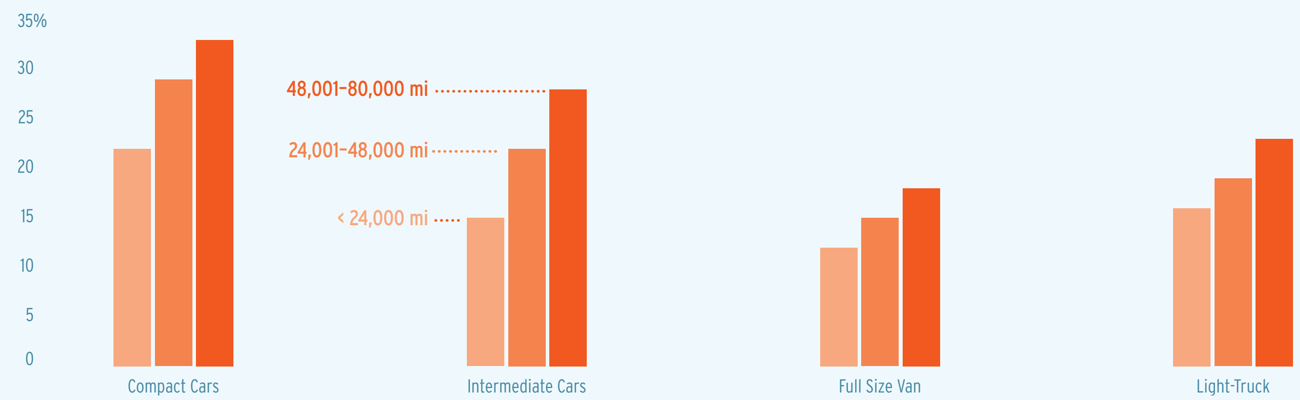
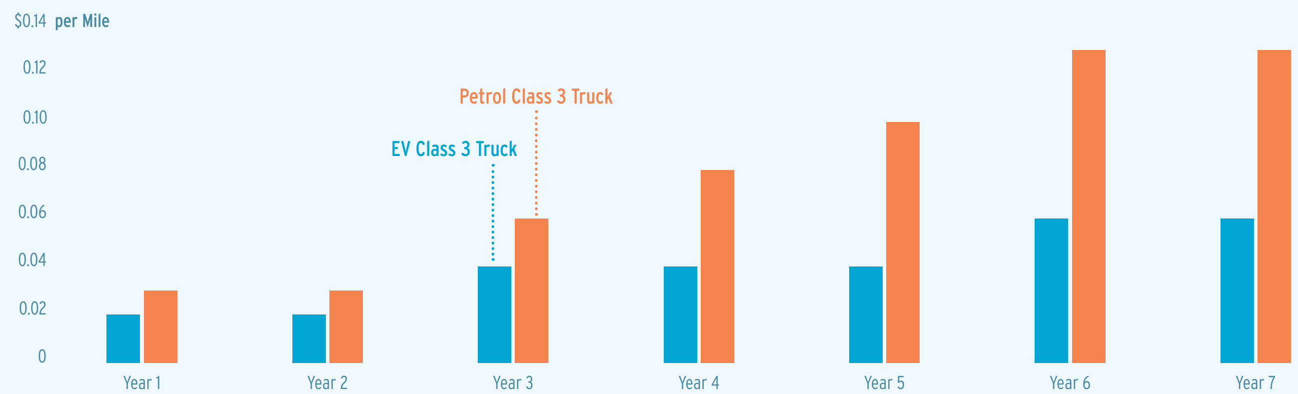


FIGURE 1P

Maintenance Cost - EV vs. ICE Vehicles



Source: Figure 1O—DOE, ORNL, Transportation Energy Data Book; Figure 1P—EC Analysis

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.

41% Commercial electricity rates were 41 percent less than residential rates in 2009.

The average retail electricity price paid by all U.S. consumers was 9 cents per kWh in 2009 (real $2005).[38] 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.[39] In contrast, commercial and industrial users pay the lowest rates, averaging 9.3 and 6.2 cents per kWh, respectively.[40] 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.

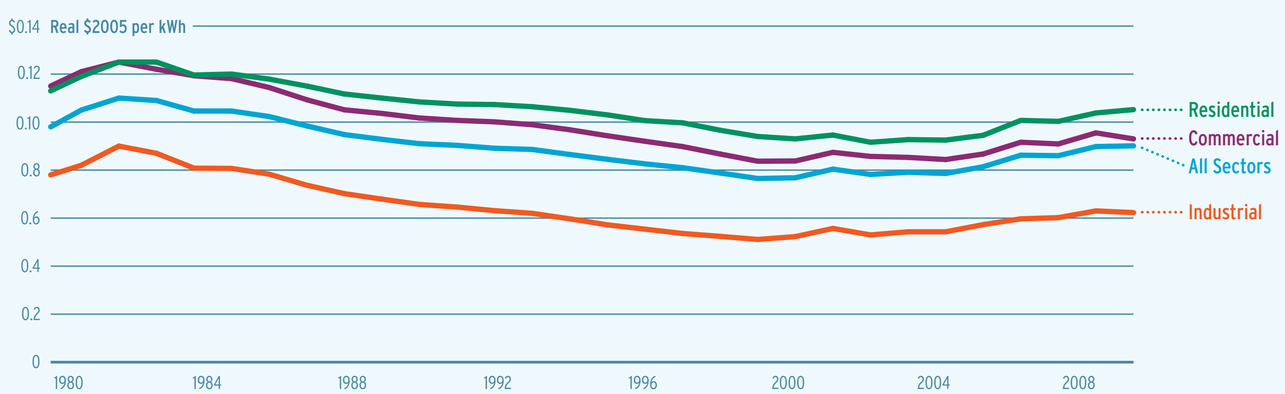
In terms of total cost economics for grid-enabled vehicles, electricity prices can have an important impact—though ultimately gasoline prices, vehicle utilization rates, and battery costs are likely to have a more significant impact. Still, in a light-duty automobile fleet application traveling 17,500 miles per year, the difference between residential and industrial electricity prices equate 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 GEV 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.

38 DOE, *AER 2009*, Table 8.10.
39 *Id.*
40 *Id.*

FIGURE 1Q
Average Retail Prices of Electricty



Source: DOE, EIA

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. The most important difference is the dominance of open-ended leasing in the commercial space, a practice that has important implications for capital management as well as battery residual value risk.

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 lessee returns the vehicle to the lessor, 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.[41]

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 strong incentive to keep the vehicle in good condition in order to maximize its value in the used vehicle market.

Figure 1R demonstrates the net result of TRAC 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

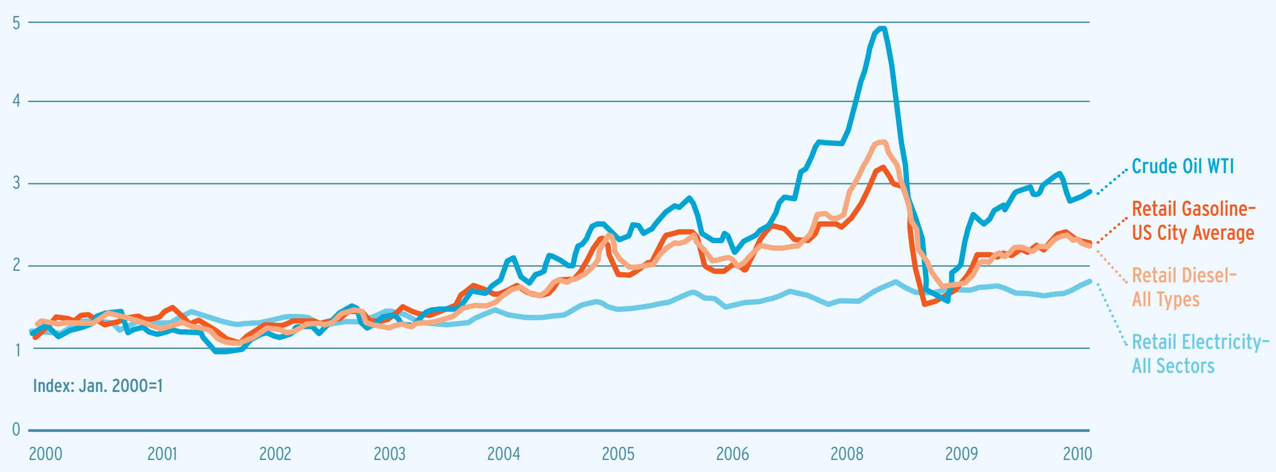
The low cost and relative stability of electricity prices provide drivers of EVs and PHEVs with a fairly high degree of certainty regarding fuel cost over time. This is in stark contrast to vehicles fueled by petroleum, which are subject to the high volatility of gasoline and diesel

41 GE Capital, Fleet Services.

FIGURE 1R
Sample TRAC Lease Outcomes

	GAIN ON SALE	LOSS ON SALE	BREAK EVEN ON SALE
Capital Cost	$22,000	$22,000	$22,000
Amortization Term	60 Months	60 Months	60 Months
Leased Months	48 Months	48 Months	48 Months
Book Value	$4,400	$4,400	$4,400
Resale Value	$5,200	$3,800	$4,400
Customer Impact	$800	-$600	$0

FIGURE 15
Change in Energy Prices (2000–2010)



Source: DOE, EIA; EC Analysis

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.[42] 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.[43]

In cases where EVs or PHEVs would meet their mission requirements, fleet operators may be willing to hedge against petroleum fuel price volatility though 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.

42 DOE, EIA, Petroleum Navigator, available at http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=M.
43 Moming Zhou, "Crude Oil Drops on Weak Demand, Rising Gasoline Inventories," Bloomberg, September 28, 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] Over the 2009 to 2014 period, the value of this market is forecast to experience a 19 percent compound annual growth rate to $65.9 billion.[46]

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.[47] Others major firms, including UPS and FedEx, have all begun using standard HEVs for delivery purposes in recent years.[48,49] 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.[50] In addition, some firms and government agencies are already moving to incorporate EVs and PHEVs into their vehicle fleet. In September 2010, the Pepsi Co. subsidiary Frito-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.[51] 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.[52] General Electric Co. recently announced the largest 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.[53] 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 improvement 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 sustainable business practices—that serve a critical operating function. The benefit they bring to the company brand image is almost certainly positive.

44 See for example, The Center for Creative Leadership, "Can 'Doing Good' Make a Difference in Job Retention and Turnover?" 2010 News Release, June 2010.
45 Verdantix, "US Sustainable Business Spending 2009-14," October 14, 2010.
46 *Id.*

47 The Coca Cola Company, "Refuel," http://www.thecoca-colacompany.com/citizenship/fleet_transportation.html, last accessed November 9, 2010.
48 FedEx, "Alternative Energy, Cleaner Vehicles," http://about.fedex.designcdt.com/corporate_responsibility/the_environment/alternative_energy/cleaner_vehicles, last accessed November 9, 2010.
49 UPS, "Alternative Fuels Drive UPS to Innovative Solutions," http://pressroom.ups.com/Fact+Sheets/Alternative+Fuels+Drive+UPS+to+Innovative+Solutions, last accessed November 9, 2010.
50 Hertz Corporation, "Hertz Commits to Electric Vehicle Mobility Platform," Press Release, September 21, 2010.
51 Frito-Lay, "Frito-Lay Starts 'Charge' on Largest Fleet of All-Electric Trucks in North America," Press Release, September 8, 2010.
52 *Id.*
53 Reuters, "GE to buy 25,000 electric cars by 2015," November 11, 2010.

Ford Motor Company's Transit Connect Electric vehicle in Chicago, Illinois.

FIGURE 1T

GEVs in Operation in Private Sector Fleets, Global (End 2010)

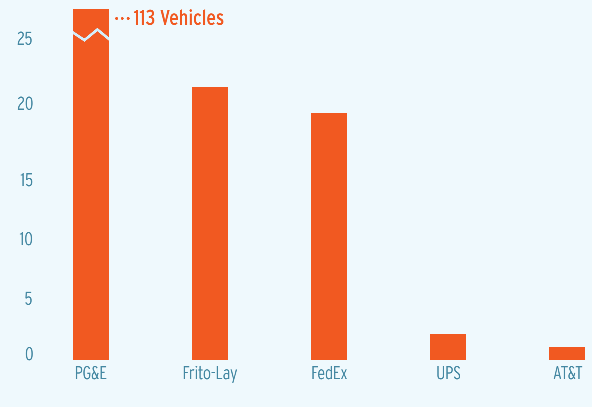
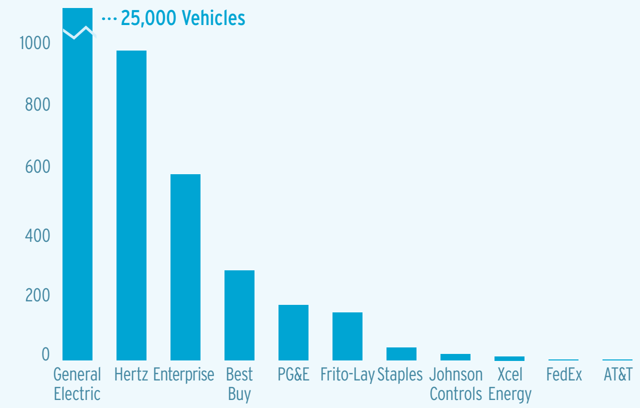


FIGURE 1U

Committed GEV Purchases in Private Sector Fleets, Global (2011 - 2015)



Source: EC Analysis

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 initiatives are about much more than brand enhancement and corporate "greenwashing." The decision-making process 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 5,300 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 evaluating 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.[54]

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 taxis to the region. The vehicles will be supported by four battery swap stations.[55] 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 technology is cost-effective.

54 EC, PRTM interviews.

55 Jim Motavalli, "Better Place rolls out Bay Area Battery Swapping EV Taxi Fleet," BNET, November 1, 2010.

PART TWO

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 fiscal, budgetary, and operational challenges that in some cases are analogous to typical consumers but can also be quite different. Federal government agencies, for example, are ultimately highly constrained in managing their budgets, and the focus tends to be on near-term cost reductions as opposed to long-term savings (though emissions and fuel-efficiency mandates are increasingly altering this dynamic). In the private sector, fleet operators do tend to focus on lifecycle vehicle costs, though they also carefully manage the tradeoffs between investing capital in new vehicles versus other productive uses.

CHAPTER 2.2

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—low 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.

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. Alternative ownership models, such as vehicle leasing, provide a key solution to this problem, but battery residuals represent uncertainty for customers.

Battery Residual Value
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 ability to store energy when they are no longer fit for automotive use. But this needs to be borne out by practical experience.

Fleet Infrastructure Issues
Even for fleets that centrally park, the cost of installing charging infrastructure may be significant. With Level II charger costs averaging $2,000 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 small fleet of EVs or PHEVs into a small charging space will bring an unusually high burden to those areas and may require upgrades to the local utility distribution network. 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 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 drivetrain for which they are optimized. Lithium-ion batteries optimized for light-duty HEV applications currently carry an average cost of $1,500 per kWh.[1] 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 batteries needed by PHEVs and EVs, they carry a lower cost in absolute terms.

Lithium-ion batteries for PHEVs and EVs currently average $600 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.[2] In heavier applications, this share can increase as the cost of battery management components also increases.

1 EC, PRTM interviews.

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.[3] 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 cycle 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.

2 PRTM analysis.
3 John Axsen et al, *Batteries for Plug-in Hybrid Electric Vehicles, Goals and State of the Technology circa 2008*, at 7, (2008).

FIGURE 2A
Battery Cost by Size and Type ($/kWh)

BATTERY TYPE	BATTERY SIZE	2010	2015	2020
Li-Ion HEV	8 kWh	$2,000	$1,625	$1,250
Li-Ion EV	25 kWh	$600	$488	$325

Cost Drivers

To date, a lack of scale has been the most significant factor behind high battery costs. As much as 70 percent of the cost of lithium-ion cells is related to raw materials, and cells account for 80 percent of pack costs.[4] Small improvements in cell production costs, while difficult, can therefore have a significant impact on pack costs. According to research conducted by the Department of Energy, a plant that is capacitized to produce 10,000 battery packs per year as opposed to 100,000 will have battery costs that are approximately 60 percent to 80 percent higher.[5] In a May 2009 Department of Energy review, research was presented that indicated using current materials and current processing technology, scaling up to 500,000 units per year would drive the cost of PHEV packs down to $363 per kWh.[6] Additionally, the research indicated other possible manufacturing developments that could push that price down farther.

4 PRTM analysis.

5 Paul A. Nelson, Danilo J. Santini, and James Barnes, "Factors Determining the Manufacturing Costs of Lithium-Ion Batteries for PHEVs," (May 2009).
6 Barnett, Brian, et. al., "PHEV Battery Cost Assessment," Tiax LLC, (May19, 2009), Presented at the May 2009 DOE Merit Review.

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 capacity. 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 12kWh 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.

FIGURE 2B
Battery Charge for Assorted Vehicle Types

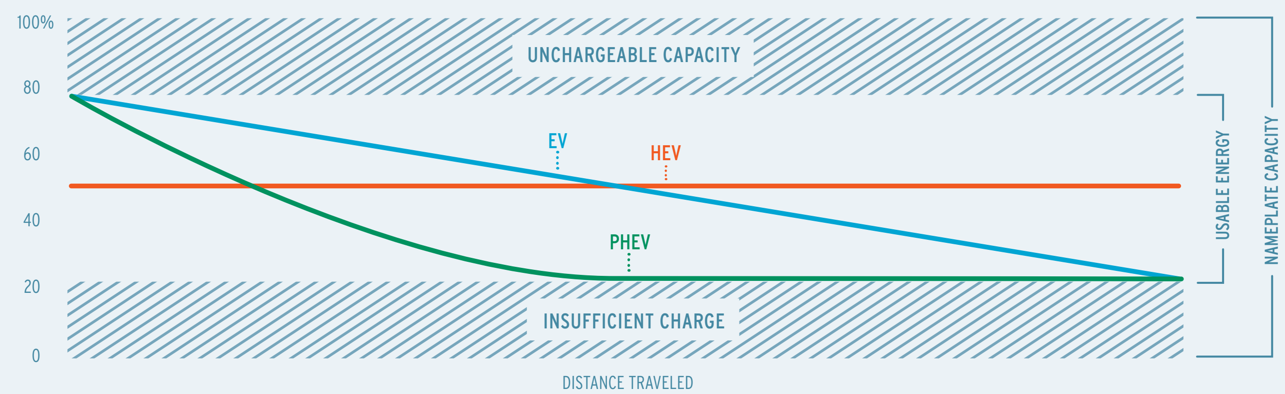
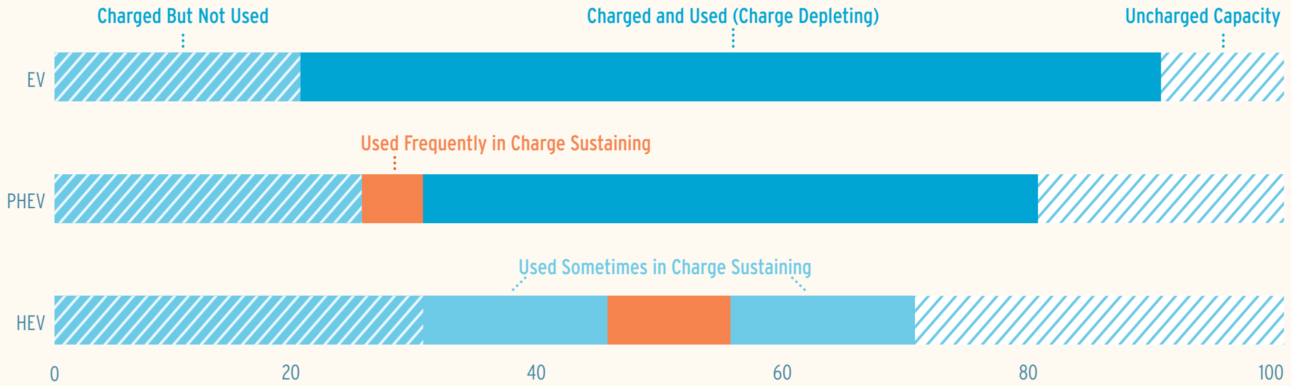


FIGURE 2C

Typical Battery Charge Patterns by Primary xEV Type



Source: DOE, NREL; PRTM Analysis

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 capacity was limited as was the number of suppliers in the market. It is also important to note that supply chain structures contained clear cost inefficiencies. For example, the lithium-ion cells for the first commercially available Chevy Volt PHEVs are being manufactured by LG Chem in South Korea.[7] They are then shipped to GM's plant in Brownstown, Michigan, and installed into the final battery packs. The structure and distribution of the lithium-ion cell industry necessitated GM's early approach. However, the company has announced plans to source a portion of Volt cells from LG Chem subsidiary Compact Power beginning in 2012. The Compact Power facility is located in Holland Michigan.[8]

The U.S. battery industry is currently entering a second phase. Unit prices have already come down to $600-$750 per kWh.[9] 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 drivetrains also contribute to higher vehicle costs. Onboard chargers, power inverters, and electric motors all represent significant portions of an electric drive vehicle's upfront costs. While relatively small with respect to battery costs, electric drive system components carry higher costs than their ICE counterparts, accounting

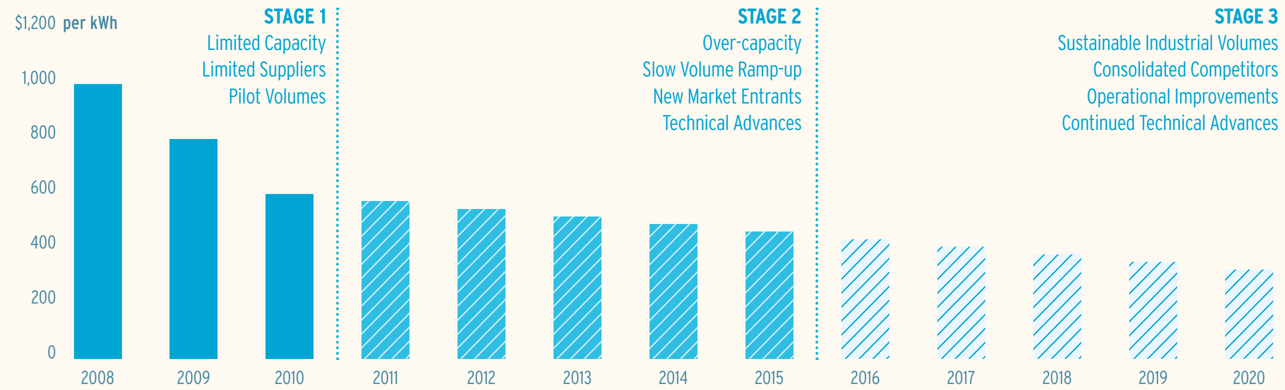
7 Soyoung Kim, "LG Chem to supply GM Volt batteries," Reuters, October 22, 2008.

8 Sam Abuelsamid, "LG Chem to build lithium ion cell factory in Holland, MI," Autoblog.com, March 14, 2010.

9 EC, PRTM interviews.

FIGURE 2D

Battery Cost Reduction Profile



Source: PRTM Analysis

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.[10] 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.[11] 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.[12] 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 (110v) will be insufficient for PHEV and EV 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

10 ORLN, Evaluation of the 2007 Toyota Camry Hybrid Synergy Drive System, (2008).

11 EC, PRTM interviews.

12 UQM Technologies, "UQM Technologies and Borg Warner Collaborate on Electric Powertrain Systems, available at http://www.uqm.com/news_article.php?aid=120.

FIGURE 2E

EV Battery Charge Times

VEHICLE	BATTERY CAPACITY	CHARGING METHOD	CHARGING POWER	FULL RECHARGE TIME
Passenger Car	24 kWh	Level 1	1.7 kW	14.1 hrs
		Level 2	3.3 kW	7.3 hrs
		Level 3	50 kW	0.5 hrs
Class 5 Truck	65 kWh	Level 1	1.7 kW	38.2 hrs
		Level 2	6.6 kW	9.8 hrs
		Level 3	50 kW	1.3 hrs
Class 7 Truck	80 kWh	Level 1	1.7 kW	47.1 hrs
		Level 2	12 kW	6.7 hrs
		Level 3	50 kW	1.6 hrs

chargers—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.[13] 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.[14] 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.[15] 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 for considering 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.[16] The earliest Level III chargers to enter the market have been designed with 50 kW of capacity, allowing them to provide 24 kWh of power in slightly less than 30 minutes, all thing being equal (in practice, today's lithium-ion batteries charge more rapidly at the lower end of the state-of-charge window, with charge times slowing as the battery's SOC increases).[17]

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.[18] In addition, the impact 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.[19] 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.[20]

13 Jim Motavalli, "Home Charging for Electric Vehicle: Costs Will Vary," New York Times, March 16, 2010.
14 *Id.*
15 See, e.g., Eric Loveday, "Siemens launches lineup of residential, commercial charging stations," Autoblog, October 25, 2010.
16 EC, PRTM interviews.
17 EC, PRTM interviews.
18 EC, PRTM interviews.
19 EC, PRTM interviews.
20 EC, PRTM interviews.

Capital Expenditures vs. Operating Expense

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.[21] 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.[22]

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.

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.[23]

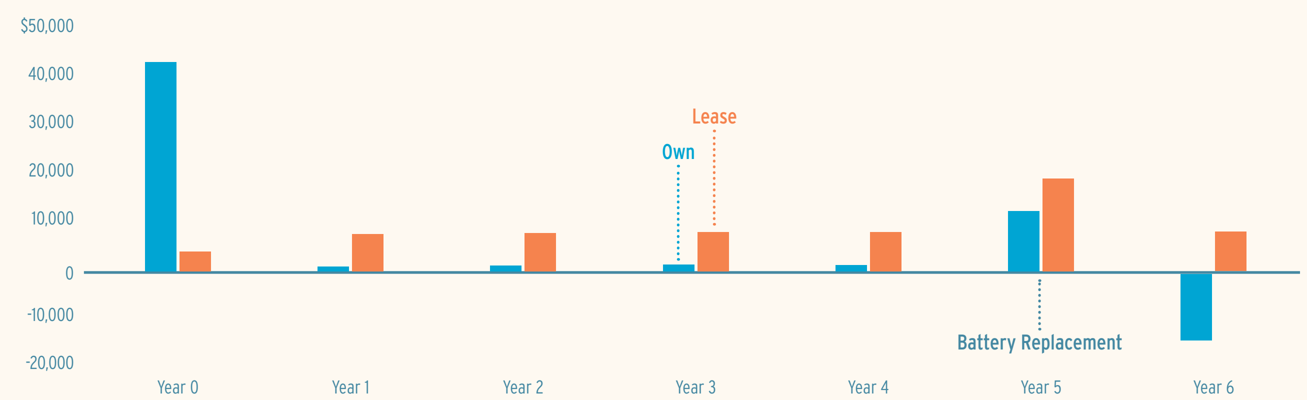
The costs and benefits of the different ownership models could ultimately have an impact on the likelihood of a fleet operator to adopt electric drive technologies. For example, the high capital cost requirements of today's HEVs, PHEVs, and EVs, particularly in applications heavier than a passenger automobile, 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 drive vehicles, although the maintenance requirements of electric drive vehicles are substantially less than those of ICE vehicles.[24]

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.

21 Bobit Publishing Company, *AFB 2010*.
22 *Id.*
23 EC, PRTM interviews.
24 EC, PRTM interviews.

FIGURE 2F

Sample Cashflow Impact of Vehicle Leasing vs. Ownership (CapEx vs. OpEx)



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.

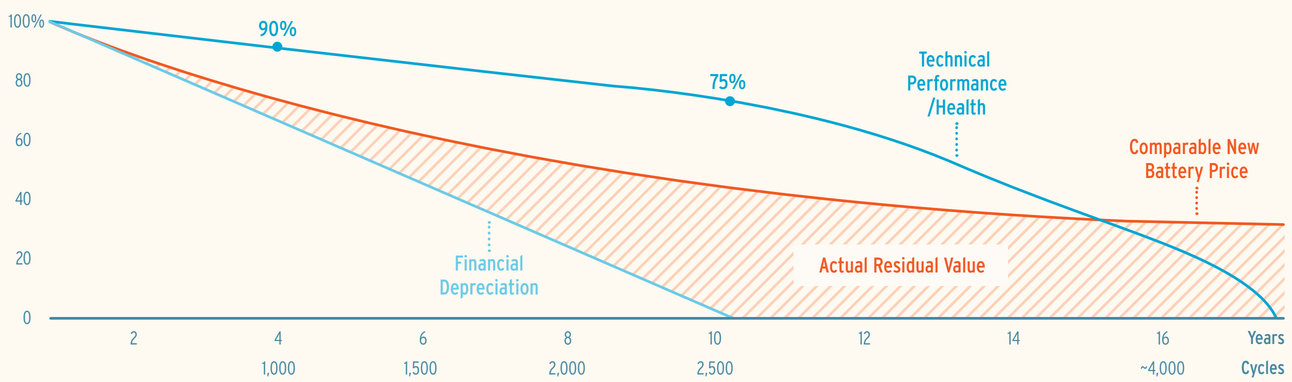
From a business model perspective, commercial leasing benefits significantly from the widespread use of open-ended leasing, or TRAC leasing. TRAC leasing has a resale risk profile that is most similar to ownership (with the added benefit of not tying up capital in vehicle acquisition). At the end of the lease period, the lessee is responsible for the net gain or loss on the resale of an individual vehicle. 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 lessees 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 readout of battery health when PHEVs and EVs are ready for resale.

FIGURE 2G

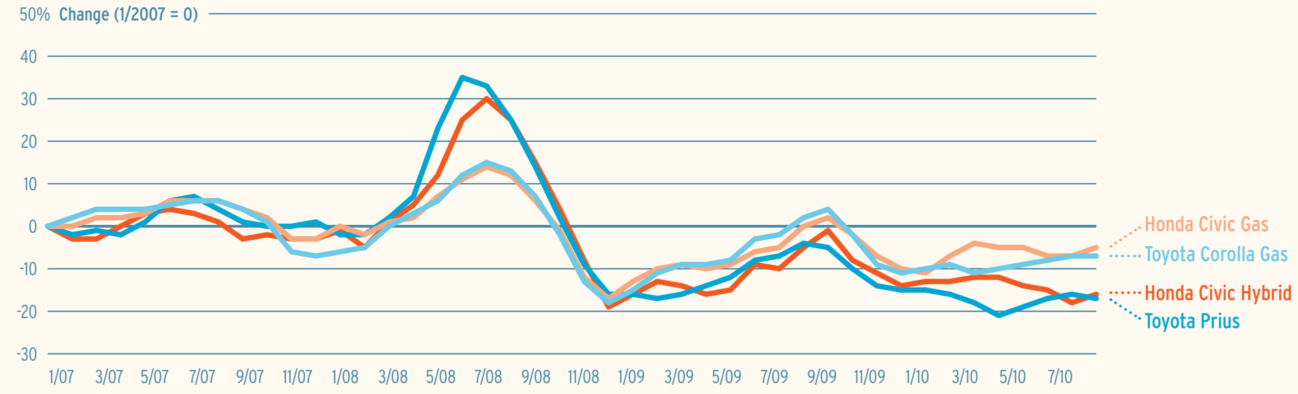
Battery Lifecycle Performance and Value



Source: PRTM Analysis

FIGURE 2H

AuctionNet® Hybrid v. Non-Hybrid Trends



Source: NADA Used Car Guide, AuctionNet

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 higher 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.[25] (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.[26] 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.[27] 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.[28] The

25 National Automobile Dealers Association, *Used Car Guide Industry Update*, October 2010, available at http://www.nada.com/b2b/moreinfo/Guidelines_201010.pdf.

26 *Id.*

27 PRTM analysis.

28 Sandia National Laboratories, "Technical and Economic Feasibility of Applying Used EV Batteries in Stationary Applications," (2003).

analysis found that four of these applications may be economically and technically feasible today.[29]

One secondary application is currently being demonstrated 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 regulation signal since October 2007 (PJM Interconnection is a regional transmission organization). It has provided both regulation services and important 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 storage needs of the grid. This demonstration also has direct application to second-life use as stationary sources of ancillary services to the grid.

70-80%

Early test data suggests that lithium-ion batteries may still have 70 to 80 percent of their potential cycle life remaining at the point where they are no longer fit for automotive use.

It is important to note that used batteries will face entrneched 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 intemrittent 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 applications, 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 suppliers 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 scrappage. General Motors recently estimated that the typical 16 kWh Chevy Volt battery pack will have "50 to 70 percent of its life left" after the expiration of GM's 8-year, 100,000 mile lithium-ion battery pack warranty."[30] 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.[31]

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.[32] Nissan has characterized the venture, 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.

29 *Id.*

30 Saqib Rahim, "General Motors Seeks Second Life for Volt Battery," Scientific American, September 22, 2010.

31 Paul Eisenstein, "Automakers mull your EV battery's life," MSNBC.com, September 29, 2010.

32 Chang-Ran Kim, "Nissan, Sumitomo in JV to Re-use, Recycle Batteries," Reuters, September 15, 2010

Fleet Infrastructure Issues

While fleets that have access to central parking facilities may find that single-point installation leads to efficiencies, 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 operation 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 chargers 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 per day at roughly four to six hours. This vehicle would fall into quadrant 1 of Figure 21. 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 possibly also require some fast charging capabilities and fall into quadrants 2 and 3 of Figure 21. 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 significant Level III capacity for EV adoption. In practice, such fleets might choose HEV or PHEV technology instead.

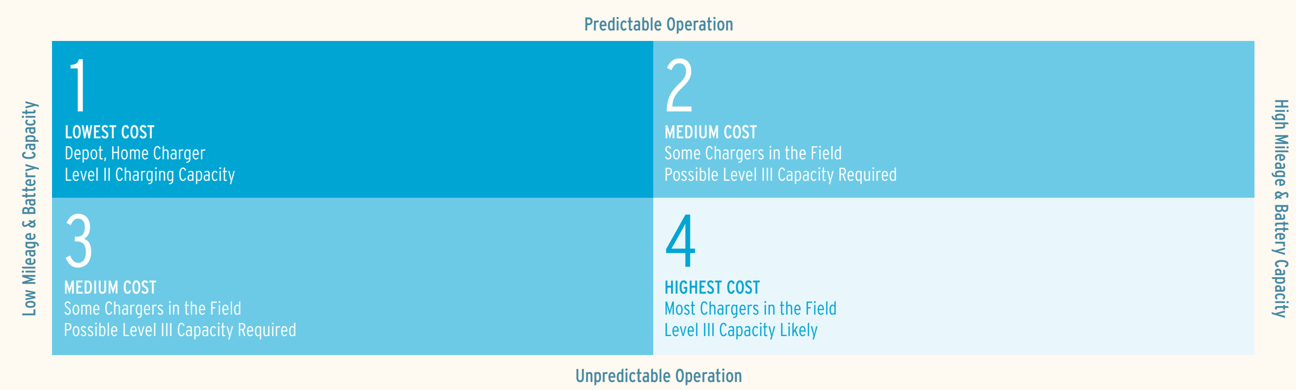
An additional factor to consider is the amount of time spent parked in a charging location. For instance, a fleet with short driving distance and predictable routes as the example for quadrant 1 above, may actually require a quadrant 4 charging infrastructure if it runs more than one shift on a vehicle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

Finally, commercial and government fleet facilities 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 disconnect size—to support special needs such as GEV charging will result in increased costs for fleet operators. Such upgrades can also require more expensive conductors, electrical panel boards, and service wires.

Upsizing the internal transformers within a large commercial or government building, such as those that might serve charging stations, may require upsizing conduits (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 21

Directional Indicator of Charging Infrastructure Costs



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 those areas, and may require upgrades to the local distribution network. 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.

Generation

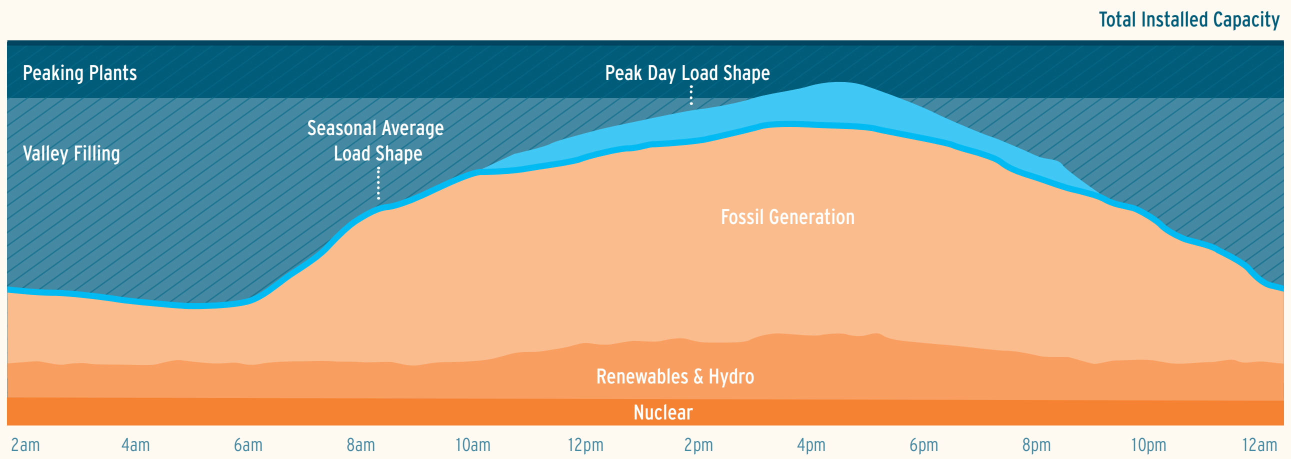
Since electricity cannot be stored, the electricity grid is constructed to meet demand during periods of highest load – typically hot summer days. In fact, to meet reliability requirements, regulators have driven utilities to overbuild their systems with a 12-20 percent reserve margin beyond forecasted 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.[33]

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.

33 Kintner-Meyer, Michael et al, "Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids Part 1: Technical Analysis," Pacific Northwest National Laboratory, January 2007.

FIGURE 2J

Stylized Load Shape for 1 Day During Peak Season



Source: Pacific Northwest National Labratory

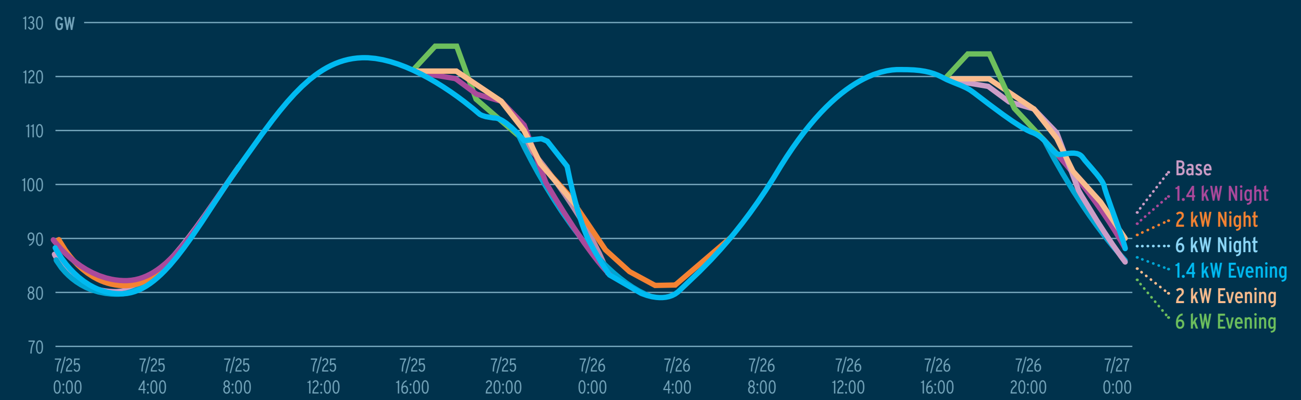
Analyzing GEV Impact On Power Generation

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

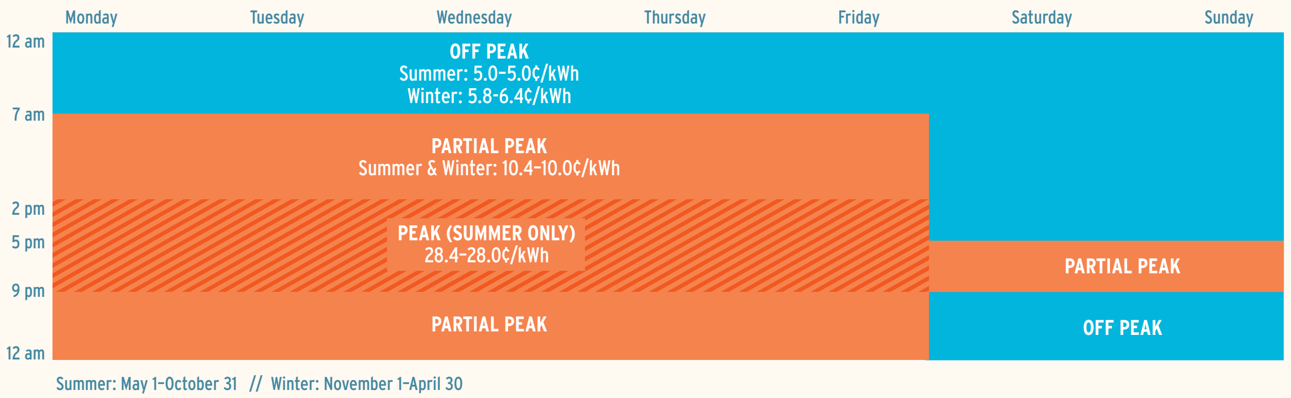
Peak Day PHEV Charging in ECAR, 2020



Source: Oak Ridge National Laboratories

FIGURE 2L

PG&E Pilot GEV Rate Plan



Source: PG&E

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.[34] DTE defines off-peak as between 11:00pm and 9:00am Monday through Friday, and anytime on weekends. The on-peak rate for EV and PHEV 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.[35] 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 in advance 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 8 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 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.

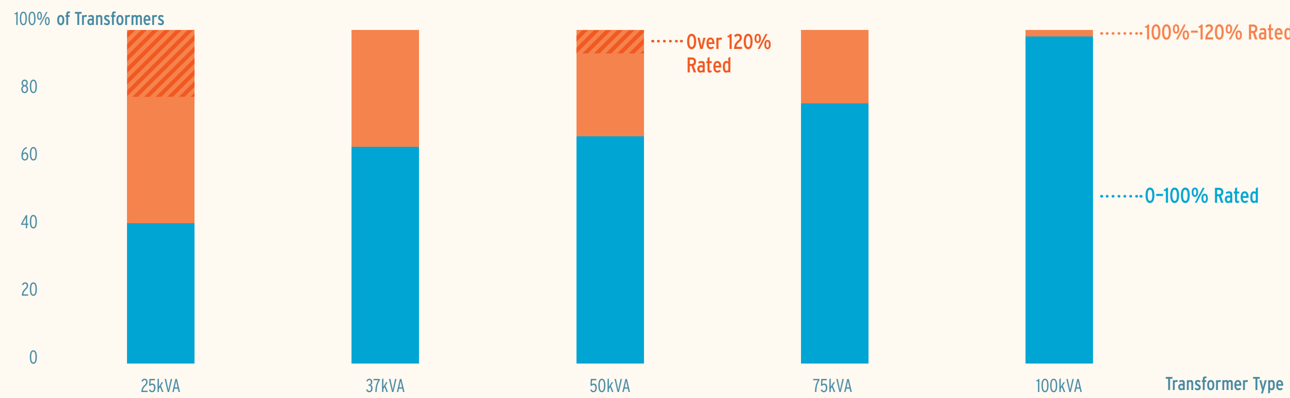
One recent analysis from the Electric Power Research Institute (EPRI) examined the impact of PHEV charging

34 DTE Energy, Plug-in Electric Vehicle Rates, available at http://www.dteenergy.com/residentialCustomers/productsPrograms/electricVehicles/pevRates.html, last accessed November 1, 2010.

35 PG&E, Electric Vehicle Charging Rate and Economics, available at http://www.pge.com/myhome/environment/pge/electricvehicles/fuelrates/index.shtml, last accessed November 1, 2010.

FIGURE 2M

Neighborhood Transformer Loading



Source: Arindam Maitra, EPRI, Effects of Electrification on the Electricity Grid, 2009

on neighborhood transformers of varying capacity.[36] 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.[37] 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.

36 Arindam Maitra, "Effects of transportation electrification on the electricity grid," EPRI (2009).

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. Each 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.[38]

In 2008, even as gasoline prices soared, recessionary conditions drove sales of all vehicles downward. Yet hybrids outperformed the broader auto market, with year-over-year sales falling by just 11 percent compared to 18 percent for autos more broadly.[39] 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.[40]

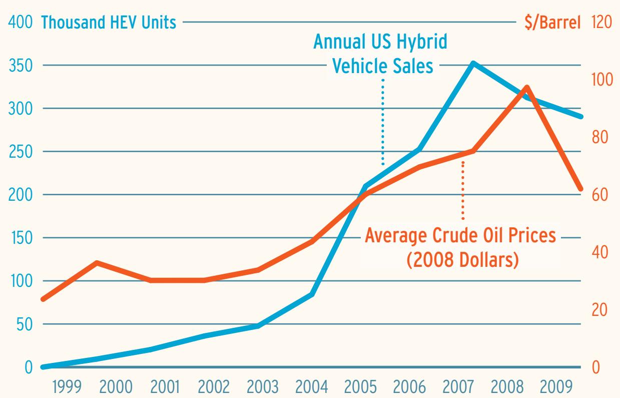
But a different story has emerged in 2010. With gasoline prices now steady at $2.70 per gallon, hybrid sales have continued to fall, while broader auto sales have rebounded. Through the first three quarters of the year, aggregate hybrids sales are down by 10 percent compared to 2009, while broader auto sales have rebounded and are set to increase by nearly 10 percent.[41] 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.[42] The market has adjusted to gasoline prices above $2.50/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

38 DOE, *AER 2009*, Table 5.24.

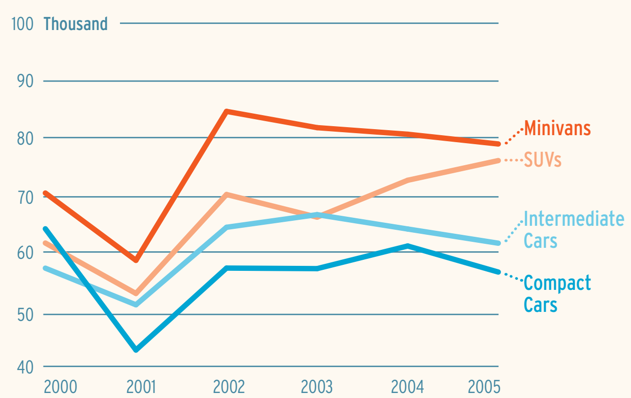
39 EC analysis based on data from DOE, EERE; Motor Intelligence.
40 *Id.*
41 Hybrid cars.com, "September 2010 Dashboard: Hybrid Sales Slide, While Clean Diesel Continues Growth," October 5, 2010.
42 WSJ Online, Auto Markets Data Center, http://online.wsj.com/mdc/public/page/2_3022-autosales.html.

FIGURE 2N
Oil Prices and HEV Sales, U.S. (Historical)



Source: DOE, EERE

FIGURE 2O
Vehicle Mileage at Auction



Source: Manheim Consulting

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.[43] There may be several reasons for this.

First, some fleet vehicles are relinquished ahead of critical maintenance milestones. For example, the average mileage of compact cars entering auction after fleet use ranged from 40,000 to 65,000 miles between 2000 and 2005.[44] 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 remarket 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 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 investments in efficiency. While some fleet managers may be more willing to focus on the bottom line and accept longer paybacks than typical consumers, competition for scarce capital places a practical limit on this approach. According to recent survey data, the average fleet operator would expect to recoup an EV investment within approximately four years.[45] 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."[46]

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 for the 80 percent of fleet vehicles that are purchased and owned in the traditional model, organizational change will be needed.

43 EC, PRTM interviews.
44 Bobit Publishing Company, AFB 2010.

45 Frost and Sullivan, "Strategic Analysis of the North American and European Electric Truck, Van and Bus Markets" (2010).
46 *Id.*
47 EC, PRTM interviews.
48 EC, PRTM interviews.

PART THREE

Identifying Fleet Opportunities

FLEET ELECTRIFICATION Florida Power and Light Company's hybrid bucket truck and electric plug-in car are shown at the ground breaking 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 that aggregate vehicles across industries with similar attributes.

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)

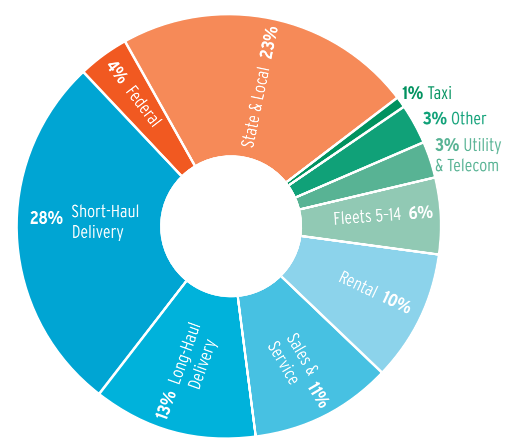
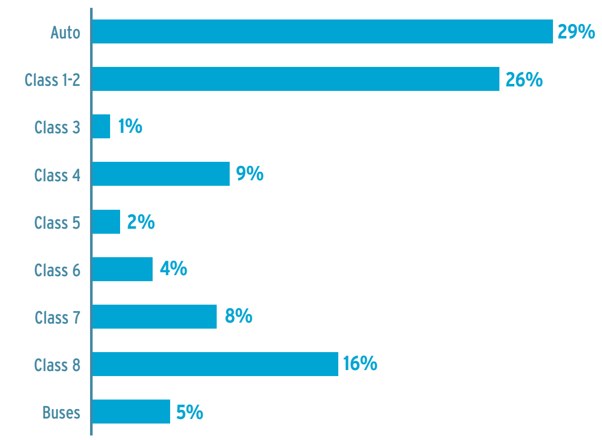


FIGURE 3B
VIO by Class (2009)



Source: PRTM Analysis

FIGURE 3C

Vehicle Segments for TCO Analysis

Source: PRTM Analysis

In addition to facilitating the creation of somewhat homogenous vehicle segments, operational characteristics were also used as modeling inputs. For example, average daily miles traveled tend to be roughly similar within each segment while also providing a key metric for 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 by vehicle weight and average miles traveled per day.

In additional 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.

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 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.

As a final note, this analysis does not consider the applicability or cost-effectiveness of other alternative fuel technologies in any fleet segment. However, some basic observations can be inferred from the fleet segmentation analysis and the operational attributes of certain fleet segments.

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

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 auto 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 powertrain). 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 remarketed value of the vehicle and/or the residual value of the battery.

FIGURE 3D

Cost Elements

CATEGORY	COST ELEMENTS	ICE	HEV	PHEV-40	EV
Capital	Vehicle (Powertrain exluding Battery)	○	◔	◕	●
	Battery	○	◔	◕	●
	Charger (Includes Installation and Software)	○	◔	◕	●
	Residual Value	Known	Some Data	Untested	○
Opex	Fuel/Electricity	●	◕	◑	○
	Maintenance/Repairs (Includes Oil, Tires, (-) Warranty)	●	◕	◔	○

Note: High GVWR Class vehicles have reported significant increases in maintenance costs in early production versions of xEVs due to both the nascent state of technology and the learning curves for repair technicians.

○ Low ◔ ◑ Med ◕ ● High

Source: PRTM Analysis

Base ICE Vehicles

Upfront 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 drivetrain 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 PHEV 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 PHEV 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.

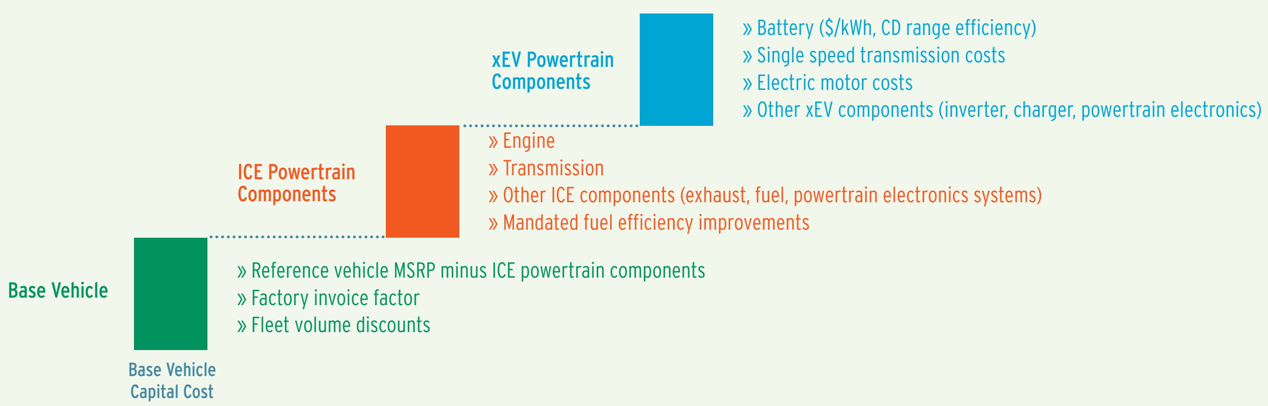
Charging Infrastructure

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.

FIGURE 3E

Key Components In Scope



Source: PRTM Analysis

Operating Costs

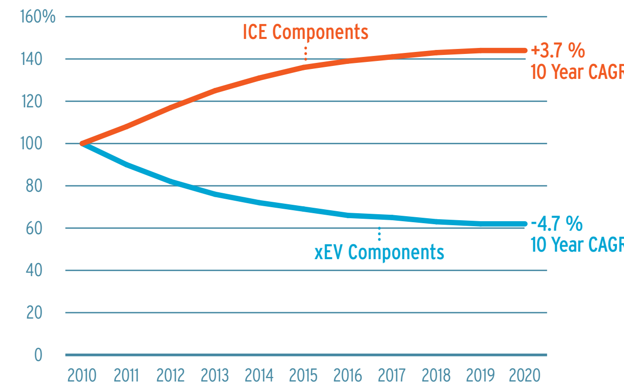
Operating costs are those costs associated with fueling and maintaining a given vehicle over its useful life. Operating costs may vary significantly based on the cost of fuel (gasoline, diesel, or electricity), the efficiency with which the energy is used, and the way the vehicle is operated.

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.

FIGURE 3G

Evolution of Vehicle Components

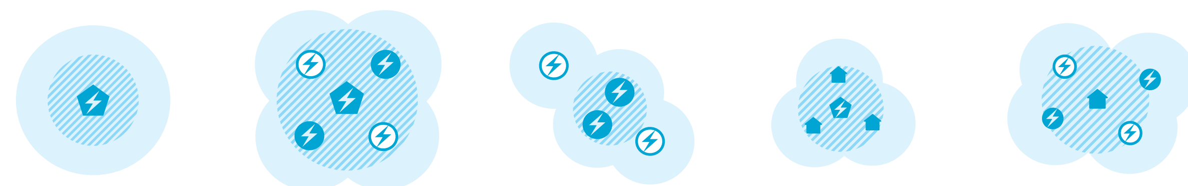


Source: PRTM Analysis

FIGURE 3F

Charging Configurations

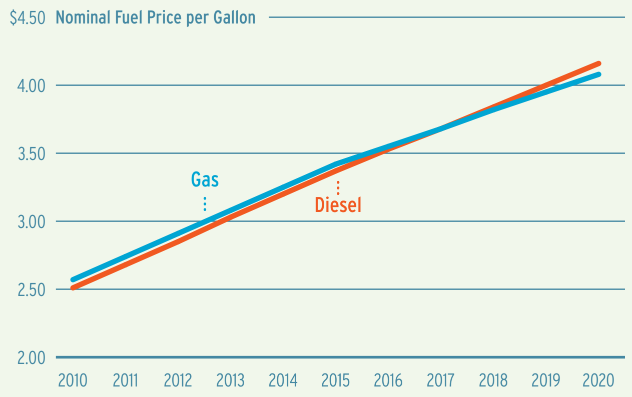
	SINGLE DEPOT	REGULAR DELIVERY	MULTIPLE SITES	COMPANY CAR COMMUTER	SALES FORCE
Description	» Single home lot for all fleet vehicles » Fleet has short, regular, and defined routes eliminating need for extraneous charging	» Fleet has regular, defined routes » Fleet has specific dwell points ideal for topping off	» Fleet has multiple locations with no central depot	» Fleet has primary daytime location » Fleet is parked overnight at home	» Fleet has multiple locations with no central depot » Fleet is parked overnight at home
Key Challenges	» Range anxiety	» Changes in route structure » Intermittent events	» Charger utilization vs. investment	» Investment in at-will employees' residence » Charger utilization vs. investment	» Complexity » Investment in at-will employees' residence
Characterized By	» Single large bank of charge stations at central depot	» Primary bank of charge stations at central depot » Extended infrastructure of public & fast charging stations	» Multiple public chargers per location	» Primary bank of charge stations at primary daytime lot » Individual home chargers at private residences	» Multiple public chargers per location » Individual home chargers at private residences » Sporadic fast charging



Central Charger Depot Bank · Public Charger · Fast Charger · Home Charger · Service Area · Charge-Depleting Range

FIGURE 3H

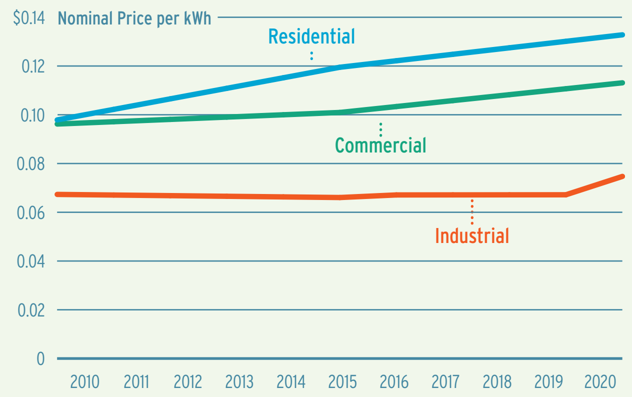
Retail Fossil Fuel Prices (2010-2020)



Source: DOE, EIA, AEO 2010

FIGURE 3I

Retail Electricity Prices (2010-2020)



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.[1,2] 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 benefit 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 cost 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.[3]

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).

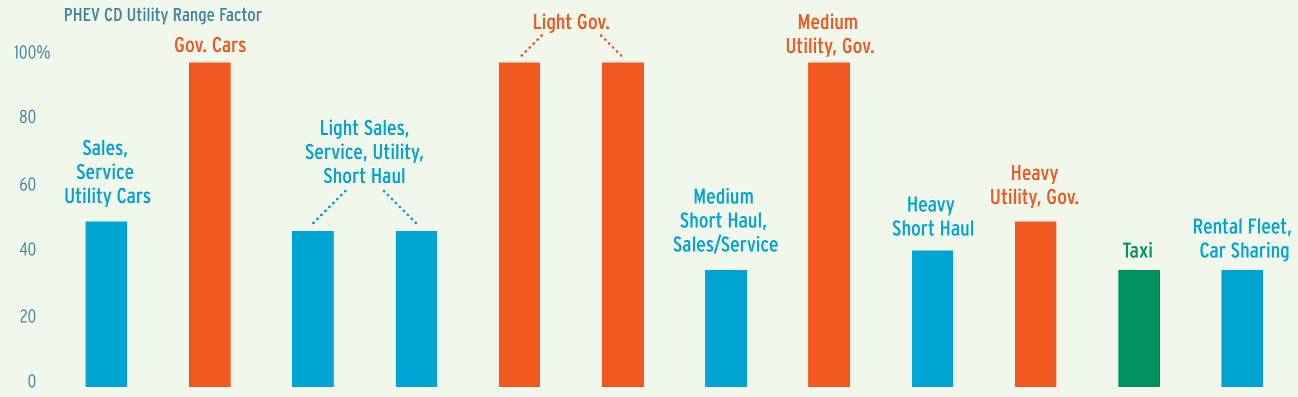
Wherever possible, the energy consumption rates for internal combustion engine vehicles in this analysis were calculated using observed fuel efficiency rates as opposed to the sticker rate or fuel-economy rating associated with EPA driving cycles. These fuel consumption rates were acquired using real 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 fuel 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.

1 DOE, EIA, Petroleum Navigator, Weekly Retail Gasoline and Diesel Prices (October 25, 2010)
2 DOE, AER 2009, Table 5.24
3 See, e.g., DOE, EIA, Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009, available online at http://www.eia.doe.gov/oiaf/1605/climate.html

FIGURE 3J

PHEV Charge-Depleting Range Utility Factor (%)



Source: PRTM Analysis

FIGURE 3K

Electric Motor Efficiency

CD RANGE EFFICIENCY	MI/KWH
Passenger Car	4.0
Class 1-2	3.1
Class 3	2.0
Class 4-5	1.5
Class 6-7	1.2

Source: PRTM Analysis

For EVs, mi/kWh applies to all miles traveled. That is, an EV can only travel in charge-depleting mode. For PHEVs, however, some portion of miles traveled will be powered by electricity and some will be fueled by petroleum fuels. Each mode has a different efficiency profile as well as exposure to different prices. Therefore, this analysis assumed the PHEV utility factors displayed in Figure 3J, which vary by vehicle weight class. A utility factor is simply the percent of total miles traveled that are powered by electricity (charge-depleting miles divided by total miles). PHEV utility factors have a significant impact on total cost and will vary depending on usage patterns and access to charging opportunities.

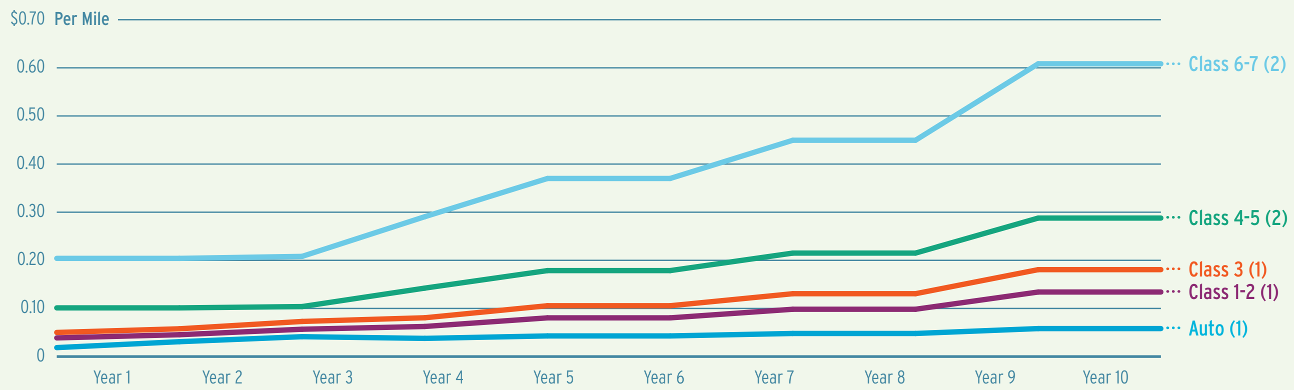
Maintenance and Repairs

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 engines are comprised 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 drivetrains. (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 3L

Maintenance and Repair Costs - ICE Vehicles



Source: (1) Auto Fleet, GE Capital, Utilimarc, and PRTM Analysis (2) Utilimarc and PRTM Analysis

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.[4] 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 is the assumed cost of capital in the model.

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.

4 In a number of states, sales taxes can be paid prorated per year of usage, deferring tax obligations. However, this as well as any additional interest tax shields are not considered by the model.

FIGURE 3M

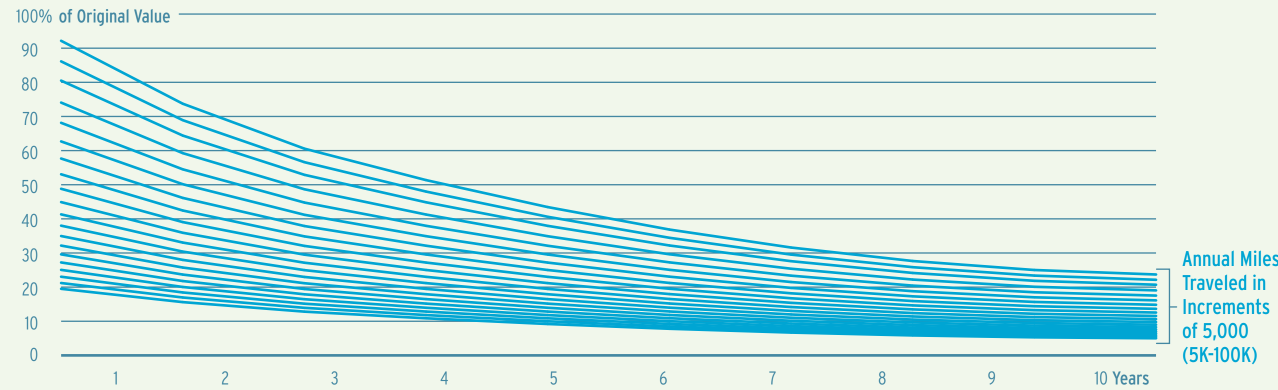
% Improvement over ICE Maintenance & Repair Costs

COST COMPONENT	HEV	PHEV-40	EV-100
Oil	5%	50%	100%
Scheduled Maintenance	3%	10%	20%
Repairs	4%	15%	30%

Source: GE Capital data and PRTM estimates

FIGURE 3N

Vehicle Depreciation Schedule



Source: PRTM Analysis

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—excluding 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 remarketed electric drive vehicles to confidently plot a separate deprecation 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 value of that capacity. For the purposes of this analysis, it was conservatively assumed that GEV 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 battery 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 2018 as battery costs begin to fall below $400/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 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 **rightsizing 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 rightsizing. 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 - Case (No Policy Incentives)

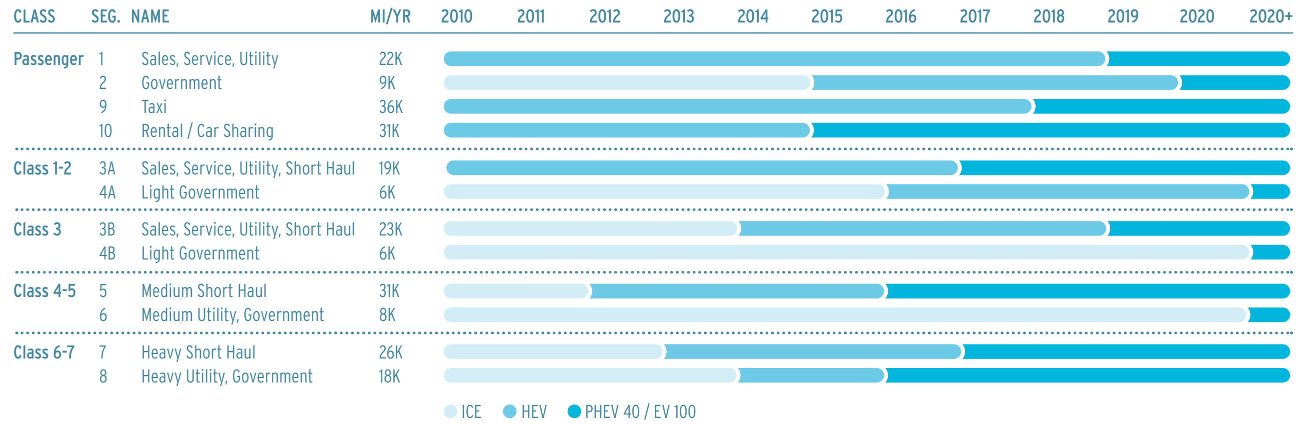


FIGURE 3P

Lowest TCO Drivetrain Technology by Year and Segment - Operations Optimized

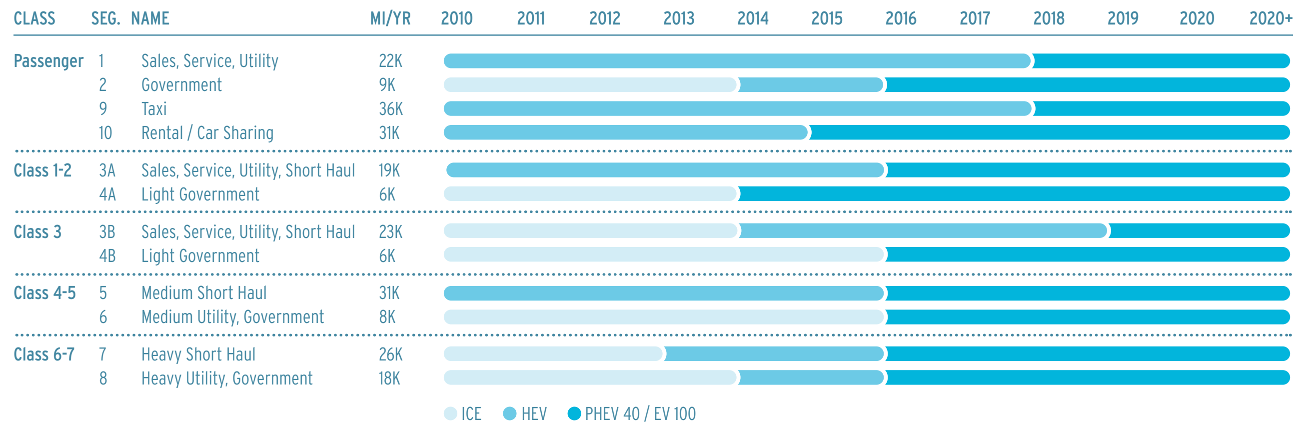
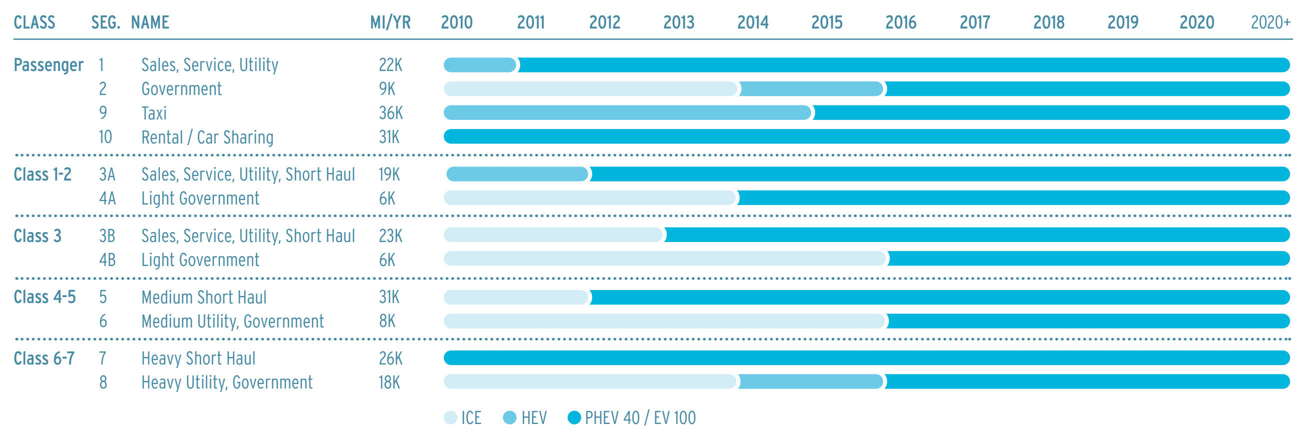


FIGURE 3Q

Lowest TCO Drivetrain Technology by Year and Segment – Operations Optimized + Government Incentives



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 percent). 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"

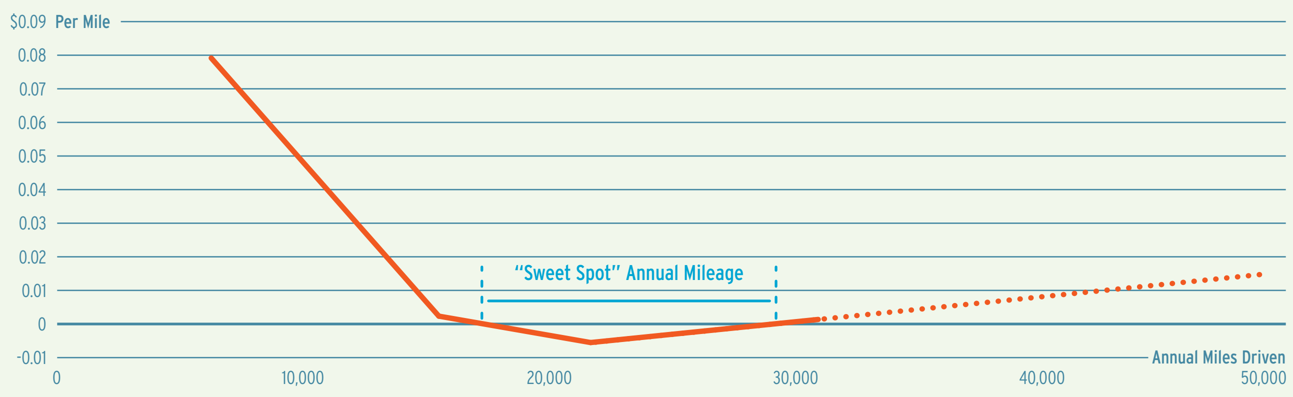
In general, the higher the annual driving distances, the lower the TCO for an electric drive vehicle with respect to an ICE for a vehicle purchased in 2018. This is due to the realization of faster energy and maintenance cost savings, resulting in an acceptable payback period. An example of this for 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.

FIGURE 3R

Total Cost of Ownership Delta for EV vs. ICE Segment 1 - Sales, Service, Utility (Base Case)



Source: PRTM Analysis

FIGURE 3S

Base Scenario - Sales, Service, Utility Cars

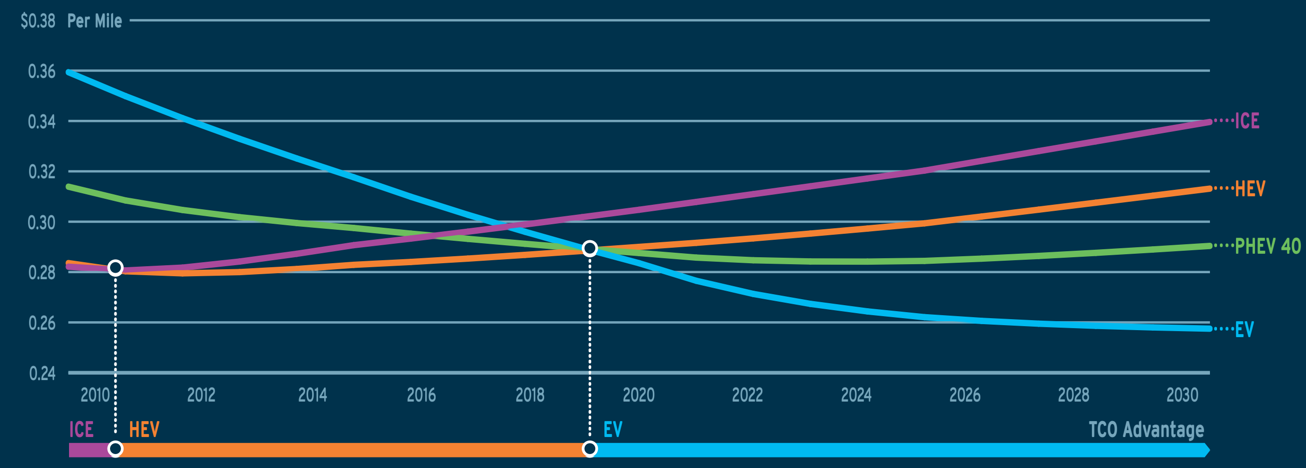


FIGURE 3T

Pessimistic Scenario - Sales, Service, Utility Cars

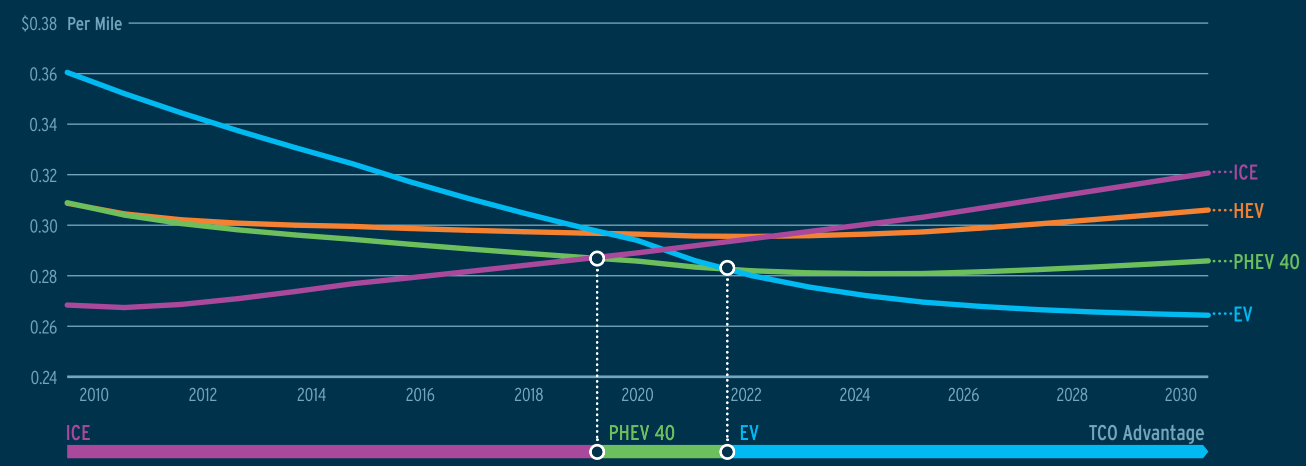
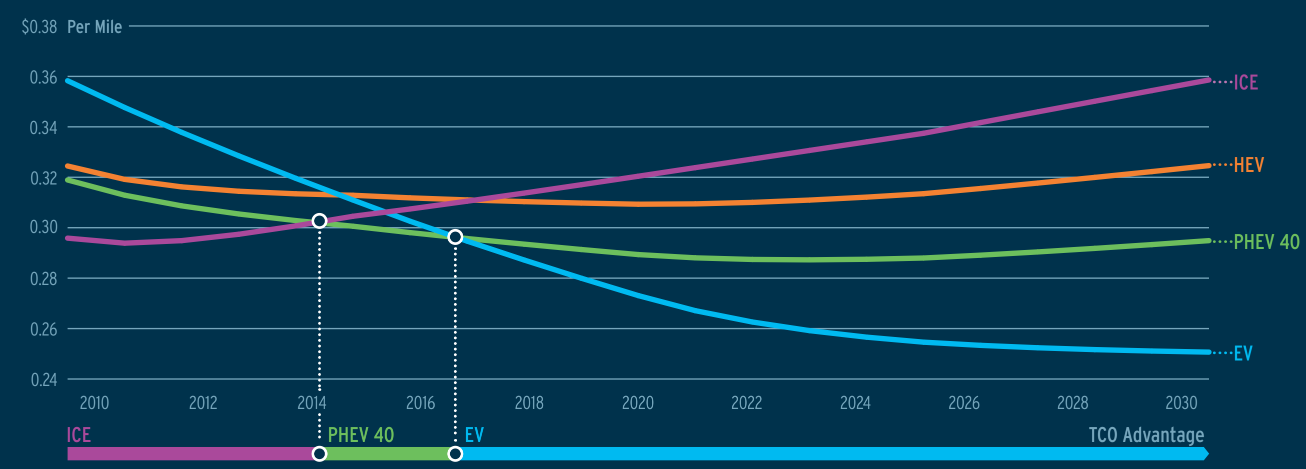


FIGURE 3U

Optimistic Scenario - Sales, Service, Utility Cars



Source: PRTM Analysis

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.

FIGURE 3V

Government Car TCO Before Right-Sizing

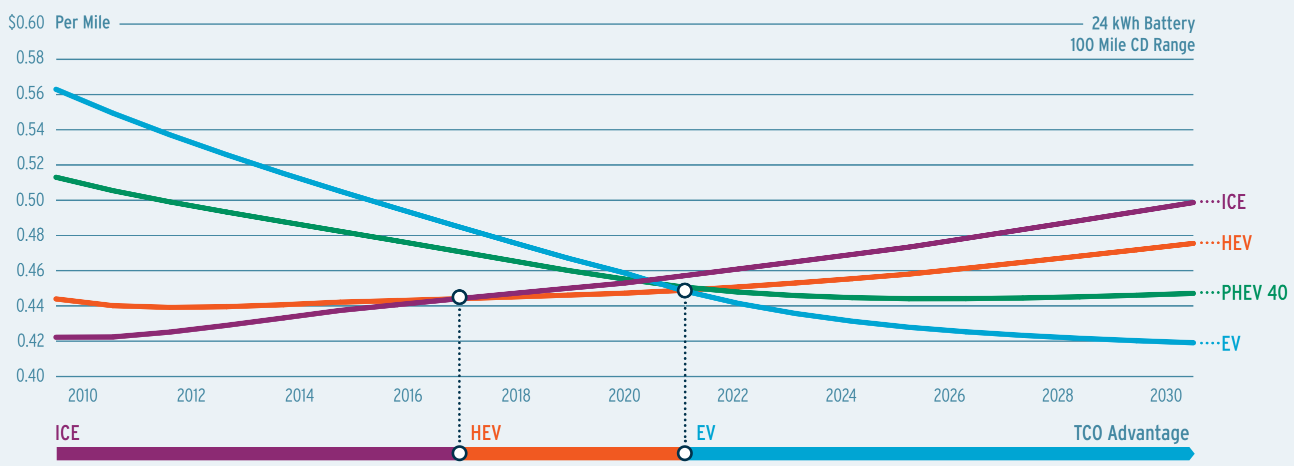
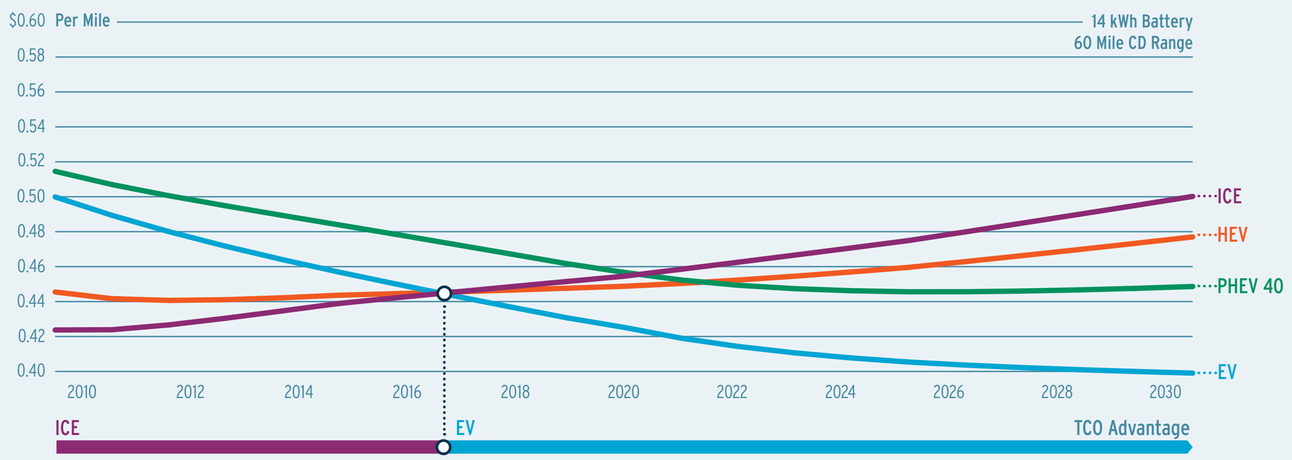


FIGURE 3W

Government Car TCO After Right-Sizing



Source: PRTM Analysis

CHAPTER 3.4

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

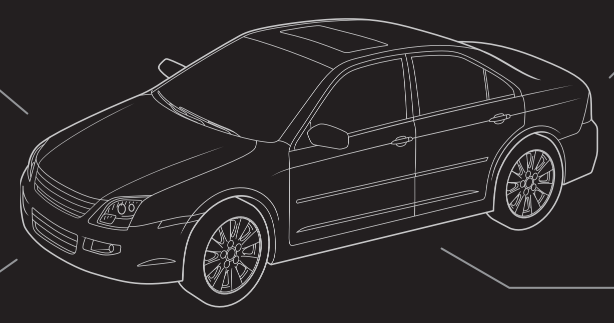
The optimized + policy case assumes that fleet operators can purchase vehicles that fit their needs and that they will use them in the manner that most efficiently lowers cost. Battery right-sizing and extended ownership periods are examples of optimized use. The optimized + policy case also incorporates 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



OPERATIONAL SPECIFICATIONS

71 mi Average Distance Segment Travels Each Day

At 71 miles, the average daily distance traveled for this segment is conducive to EV-100 use. It is also high enough to drive a relatively fast payback on upfront costs. For a PHEV-40, the assumed utility factor is 51 percent.

6 years Average Ownership Duration

At approximately six years, the average ownership duration for this segment would likely require battery replacement for PHEVs and EVs. The timing of battery replacement can significantly impact TCO.

$3,800 Infrastructure Cost Per Vehicle

In 2010, charging infrastructure cost per segment 1 vehicle is $3,800 assuming workplace, home, and some public charging for EV-100. By 2020, the cost is expected to fall to $2,400.

INFRASTRUCTURE TOPOLOGY

Home Charging + Roaming

Since these vehicles are often assigned to employees and can be used for personal driving in addition to work-related trips, they typically are taken home by employees at night and are not returned to a central depot. As a result, the charging infrastructure needed to support this segment is a distributed network, including infrastructure at the employees' homes as well as some public infrastructure to support occassional trips in excess of the average.

Central Charger Depot Bank | Public Charger | Fast Charger | Home Charger

Total Cost of Ownership (Base Case)

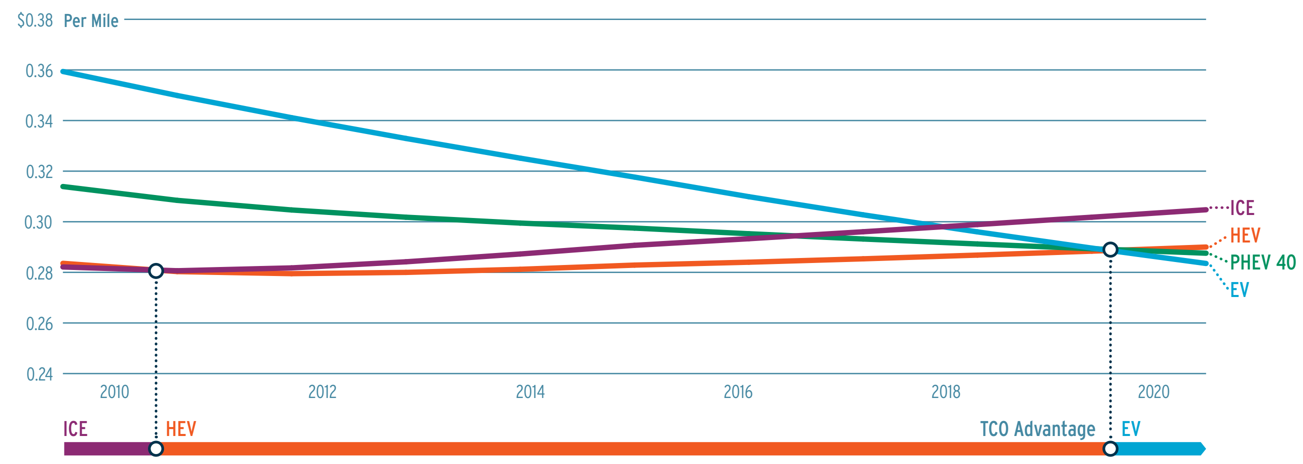
Due to the relatively high mileage of the segment, a positive payback on the greater initial investment of an electric drive vehicle is achieved earlier than fleet segments that have lower annual mileage. As is shown in Figure 3W, the HEV is the first electric drive vehicle to achieve TCO parity with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

Internal combustion engine vehicle cost increases between 2010 and 2020 will more than offset the

FIGURE 3X

2010-2020 xEV Total Cost of Ownership – Base Case



Vehicle Specifications

ICE	2010	2020
Base Drivetrain	3.0L SI / 6 Spd. Auto	3.0L SI / 6 Spd. Auto
Base Engine Cost	$1,450	$1,300
Base Transmission Cost	$1,200	$1,100
Exhaust System Cost	$600	$575
Fuel System Cost	$100	$90
Mandated Fuel Efficiency Improvements ($/% of MPG increase)	$25	$50
Fuel Economy	23 MPG	32 MPG

PHEV-40	2010	2020
Electric Range	40 mi	40 mi
Battery Cost	$660	$358
Battery Size	12 kWh	12 kWh
PHEV-40 Battery Life	150,000	150,000
Electric Motor Cost	$990	$540
Inverter Cost	$1,620	$900
Charger Size	3.3 kW	3.3 kW
On-Board Charger Cost	$580	$390

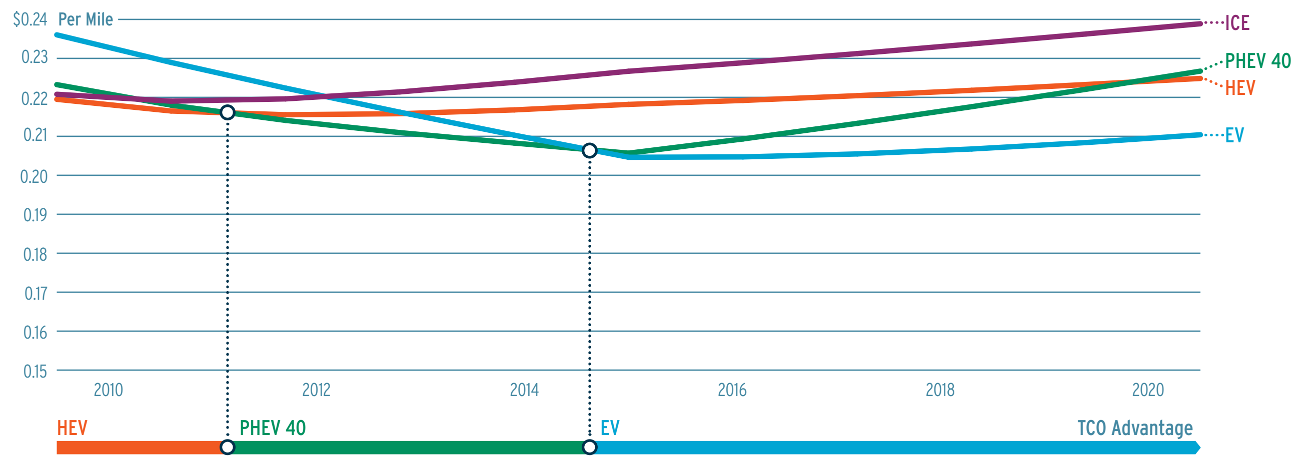
HEV	2010	2020
Battery Cost	$1,200	$650
Battery Size	1.5 kWh	1.5 kWh
HEV Battery Life	200,000 mi	200,000 mi
Electric Motor Cost	$770	$420
Inverter Cost	$1,260	$700

EV-100	2010	2020
Battery Cost	$600 /kWh	$325 /kWh
Battery Size	24 kWh	24 kWh
EV Battery Life	125,000mi	125,000
CD Range Efficiency	4.0 mi/kWh	4.6 mi/kWh
Electric Motor Cost	$990	$540
Inverter Cost	$1,620	$900
Charger Size	5 kW	5 kW
On-Board Charger Cost	$875	$600
1-Spd Transmission	$400	$380

Source: PRTM Analysis

FIGURE 3Y

2010-2020 xEV Total Cost of Ownership – Optimized with Incentives



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, 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 point to transfer ownership is right after a new battery has been purchased (approximately six years in segment 1). 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

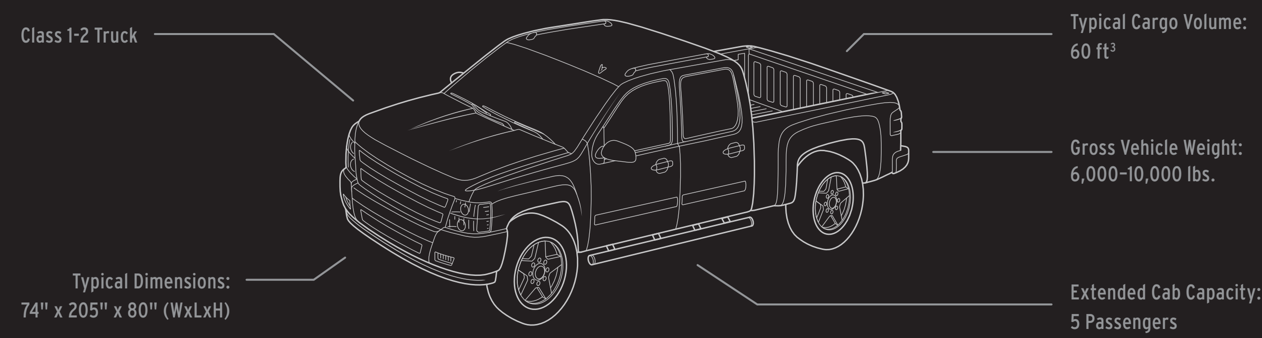
The total cost of ownership in the base case does not include the current federal tax incentives of $7,500 per vehicle. When this is factored in, GEVs become financially attractive for segment 1 fleet operators almost immediately. As shown in Figure 3Y, the total cost of ownership with government incentives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

CASE STUDY / SEGMENT 3A

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.

VEHICLE CHARACTERISTICS



OPERATIONAL SPECIFICATIONS

75 mi Average Distance Segment Travels Each Day

At 75 miles, the average daily distance traveled by this segment is conducive to EV-100 use. It is also high enough to drive a relatively fast payback on upfront costs. The assumed utility factor for PHEV-40s is 48 percent.

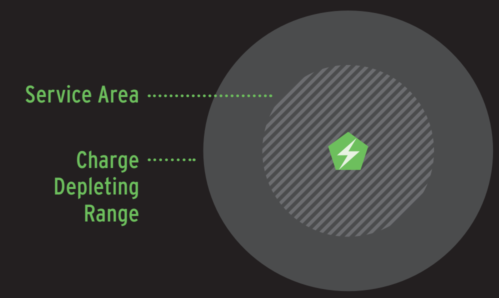
7 Years Average Ownership Duration

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.

$3,400 Infrastructure Cost Per Vehicle

The 2010 charging infrastructure cost for segment 3a vehicles is $3,400, assuming predominantly Level II charging. By 2020, the cost is expected to fall to $2,400 per vehicle.

INFRASTRUCTURE TOPOLOGY



Central Depot

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 will not typically travel further than the CD range of an EV-100.

Central Charger Depot Bank · Public Charger · Fast Charger · Home Charger

Total Cost of Ownership (Base Case)

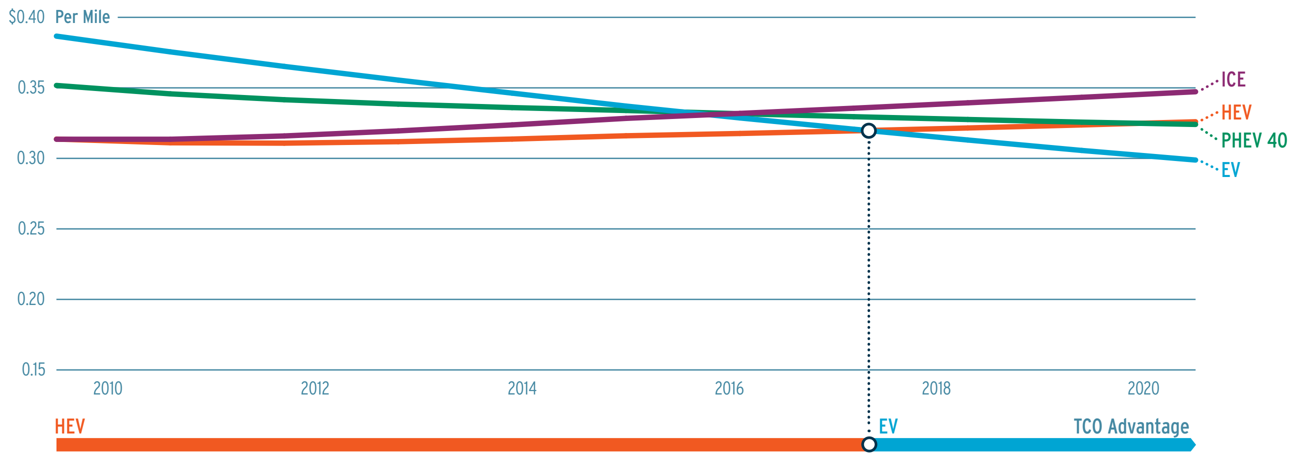
The annual driving distance of approximately 19,000 miles for vehicles within this segment is sufficient to reach the "sweet spot" in the operating cost curve. In the base case, HEV becomes the most cost effective technology in approximately 2011. Following this, EV will achieve cost parity with HEV 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

FIGURE 3Z

2010-2020 xEV Total Cost of Ownership – Base Case



Vehicle Specifications

ICE	2010	2020
Base Drivetrain	4.3L Gas / 2WD Auto	4.3L Gas / 2WD Auto
Base Engine Cost	$2,030	$1,820
Base Transmission Cost	$1,800	$1,650
Exhaust System Cost	$840	$840
Fuel System Cost	$140	$126
Mandated Fuel Efficiency Improvements ($/% of MPG increase)	$30	$60
Fuel Economy	16 MPG	21 MPG

PHEV-40	2010	2020
Electric Range	40 mi	40 mi
Battery Cost	$660	$358
Battery Size	14.3 kWh	14.3 kWh
PHEV-40 Battery Life	150,000 mi	150,000 mi
Electric Motor Cost	$1,188	$648
Inverter Cost	$1,944	$1,080
Charger Size	4 kW	4 kW
On-Board Charger Cost	$693	$475

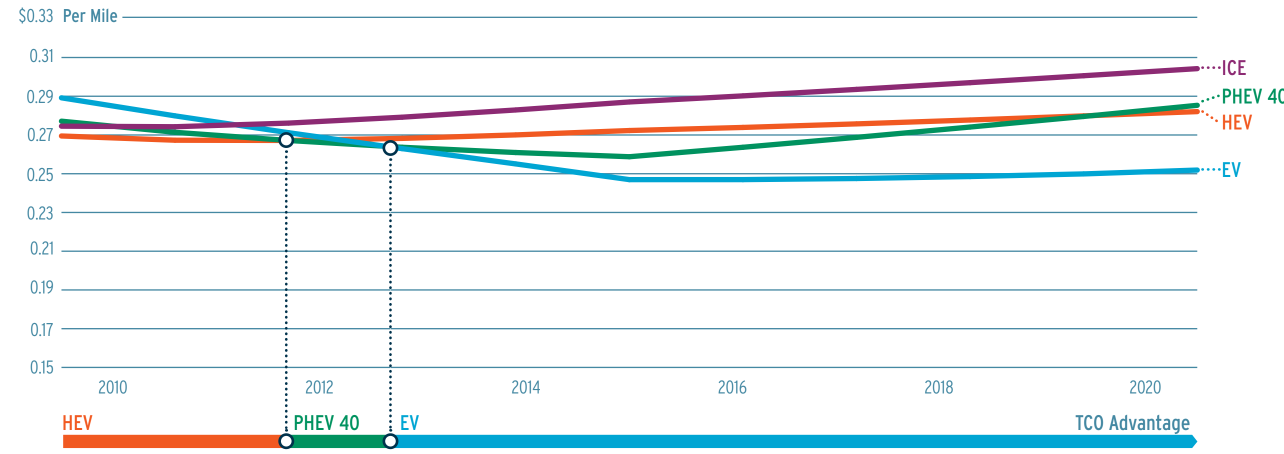
HEV	2010	2020
Battery Cost	$1,200	$650
Battery Size	1.8 kWh	1.8 kWh
HEV Battery Life	200,000 mi	200,000 mi
Electric Motor Cost	$924	$504
Inverter Cost	$1,512	$840

EV-100	2010	2020
Battery Cost	$600 /kWh	$325 /kWh
Battery Size	29 kWh	29 kWh
EV Battery Life	125,000 mi	125,000 mi
CD Range Efficiency	3.1 mi/kWh	3.5 mi/kWh
Electric Motor Cost	$1,188	$648
Inverter Cost	$1,944	$1,080
Charger Size	6 kW	6 kW
On-Board Charger Cost	$1,050	$720
1-Spd Transmission	$600	$570

Source: PRTM Analysis

FIGURE 3AA

2010-2020 xEV Total Cost of Ownership – Optimized with Incentives



Policy Variables

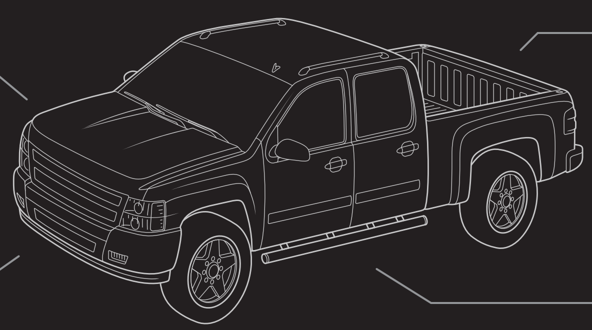
While the long-term outlook for EV costs in segment 3a looks promising compared to the other drivetrain technologies, there will still be a need for early incentives to stimulate demand and supply of plug-in light trucks. To assess the impact of these potential incentives on the ownership cost, it has 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.

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



OPERATIONAL SPECIFICATIONS

22 mi Average Distance Segment Travels Each Day

At 22 miles, the average daily distance traveled for this segment is technically conducive to EV-100 use; however reasonable payback periods would require battery right-sizing. The utility factor for PHEV-40s is 100 percent.

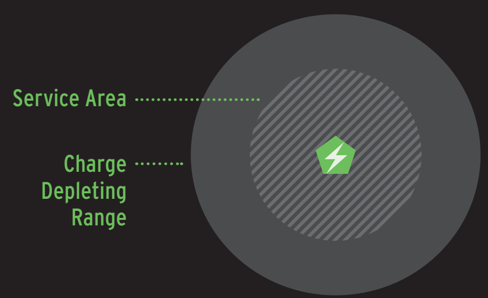
10 Years Average Ownership Duration

At 10 years, the ownership duration of segment 4a vehicles would not necessitate battery replacement based on the daily miles traveled. Battery right-sizing could change this, however.

$3,400 Infrastructure Cost Per Vehicle

The 2010 cost for charging infrastructure for segment 4a is $3,400, assuming predominantly Level II charging. By 2020, the cost is expected to fall to $2,400 per vehicle.

INFRASTRUCTURE TOPOLOGY



Central Depot
Similar to the commercial segment, these vehicles are returned to a central depot where they can be charged overnight. The vast majority of the charging requirements for these vehicles are likely to be supported by overnight charging. Daytime charging away from the depot is almost never required as these vehicles will rarely travel further than the CD range will support.

Central Charger Depot Bank · Public Charger · Fast Charger · Home Charger

Total Cost of Ownership (Base Case)

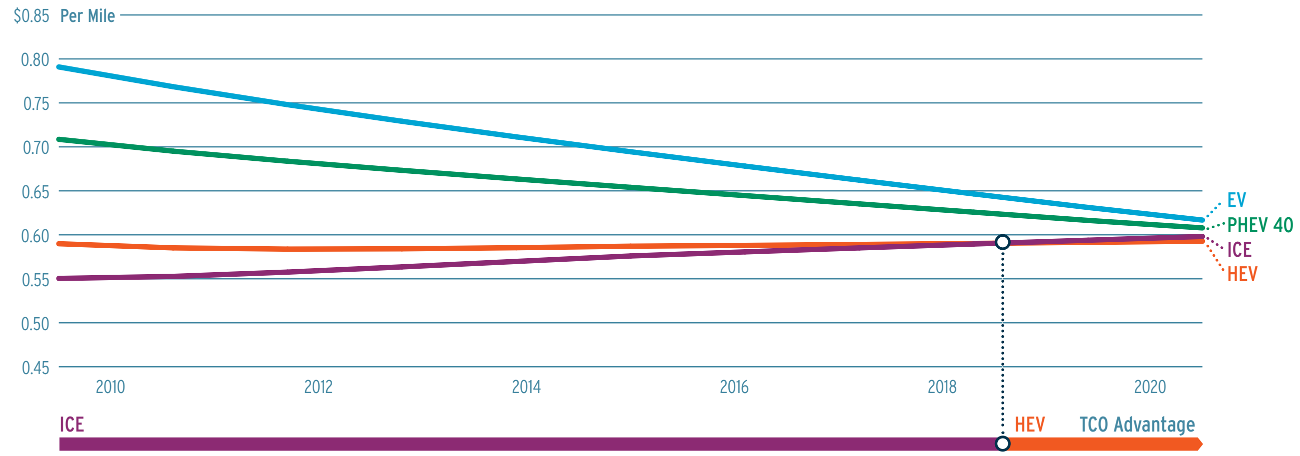
The annual mileage of approximately 6,000 miles per year for segment 4a requires significant reductions in GEV drivetrain costs to become cost effective compared to ICE. In 2010, the incremental vehicle price for an EV is almost $18,000. Meanwhile, because of the low annual mileage, the discounted lifetime 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

FIGURE 3BB

2010-2020 xEV Total Cost of Ownership



Vehicle Specifications

ICE	2010	2020
Base Drivetrain	4.3L Gas / 2WD Auto	4.3L Gas / 2WD Auto
Base Engine Cost	$2,030	$1,820
Base Transmission Cost	$1,800	$1,650
Exhaust System Cost	$840	$805
Fuel System Cost	$140	$126
Mandated Fuel Efficiency Improvements ($/% of MPG increase)	$30	$60
Fuel Economy	16 MPG	21 MPG

PHEV-40	2010	2020
Electric Range	40 mi	40 mi
Battery Cost	$660	$358
Battery Size	14.3 kWh	14.3 kWh
PHEV Battery Life	150,000	150,000
Electric Motor Cost	$1,188	$648
Inverter Cost	$1,944	$1,080
Charger Size	4 kW	4 kW
On-Board Charger Cost	$693	$475

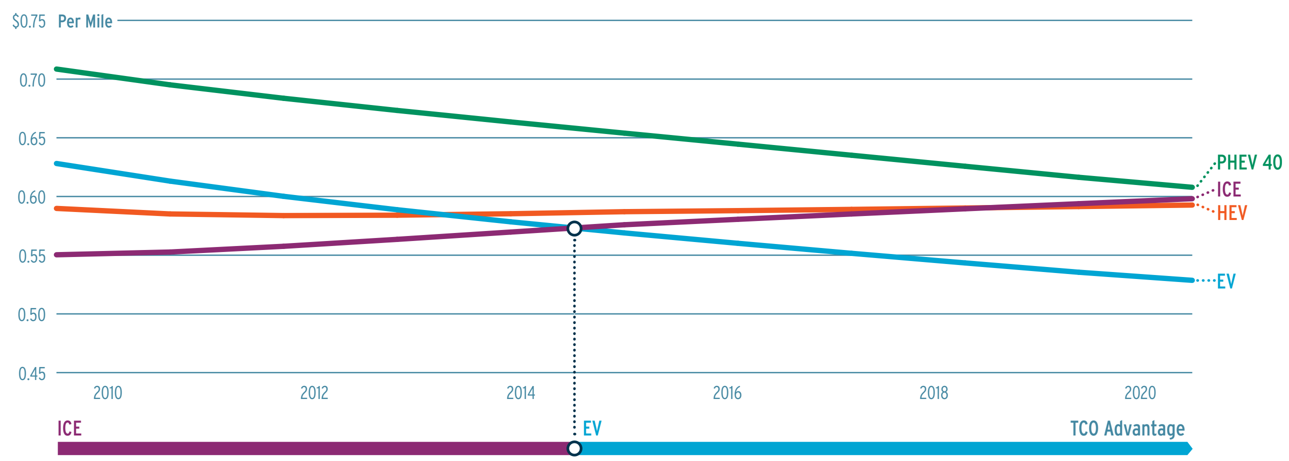
HEV	2010	2020
Battery Cost	$1,200	$650
Battery Size	1.8 kWh	1.8 kWh
HEV Battery Life	200,000 mi	200,000 mi
Electric Motor Cost	$924	$504
Inverter Cost	$1,512	$840

EV-100	2010	2020
Battery Cost	$600 /kWh	$325 /kWh
Battery Size	29 kWh	29 kWh
EV Battery Life	125,000 mi	125,000 mi
CD Range Efficiency	3.1 mi/kWh	3.5 mi/kWh
Electric Motor Cost	$1,188	$648
Inverter Cost	$1,944	$1,080
Charger Size	6 kW	6 kW
On-Board Charger Cost	$1,050	$720
1-Spd Transmission	$600	$570

Source: PRTM Analysis

FIGURE 3CC

2010-2020 xEV Total Cost of Ownership Optimized for Application



that requires optimization for cost effective operation in this segment is the battery capacity. Based on current offerings, it is 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.

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.

VEHICLE CHARACTERISTICS

Class 4-5 Truck

Typical Cargo Volume: 320 ft³

Gross Vehicle Weight: 14,001–19,500 lbs.

Typical Dimensions: 90" x 230" x 96" (WxLxH)

Standard Cab Capacity: 3 Passengers

OPERATIONAL SPECIFICATIONS

100 mi Average Distance Segment Travels Each Day

At 100 miles, the average daily distance traveled for this segment is conducive to EV-100 use. It is also high enough to drive a relatively fast payback on upfront costs. The utilization rate for PHEV-40s is 36 percent.

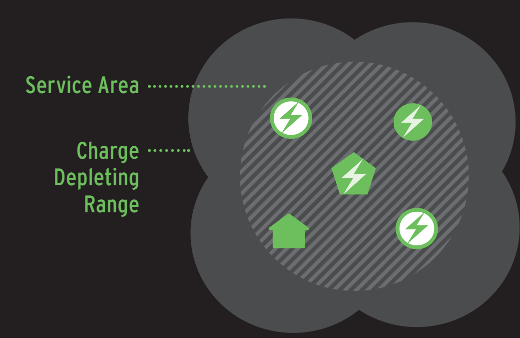
10 Years Average Ownership Duration

The 10-year average ownership period of vehicles in this segment would include at least one battery replacement based on daily miles traveled.

$3,700 Infrastructure Cost Per Vehicle

The 2010 infrastructure cost for segment 5 vehicles is $3,700 assuming some access to public charging is required. By 2020, the cost is expected to fall to $2,200 per vehicle.

INFRASTRUCTURE TOPOLOGY



CENTRAL DEPOT + PUBLIC CHARGING

Due to the high mileage of many of the vehicles within the segment, there will be some daytime charging. Due to the high utilization of these vehicles, fast charging will likely be needed to fill a portion of the daytime charging needs. Additionally, there may be applications for which Level 2 public charging is used during the day (where the vehicle is parked for a sufficient amount of time to "top-off").

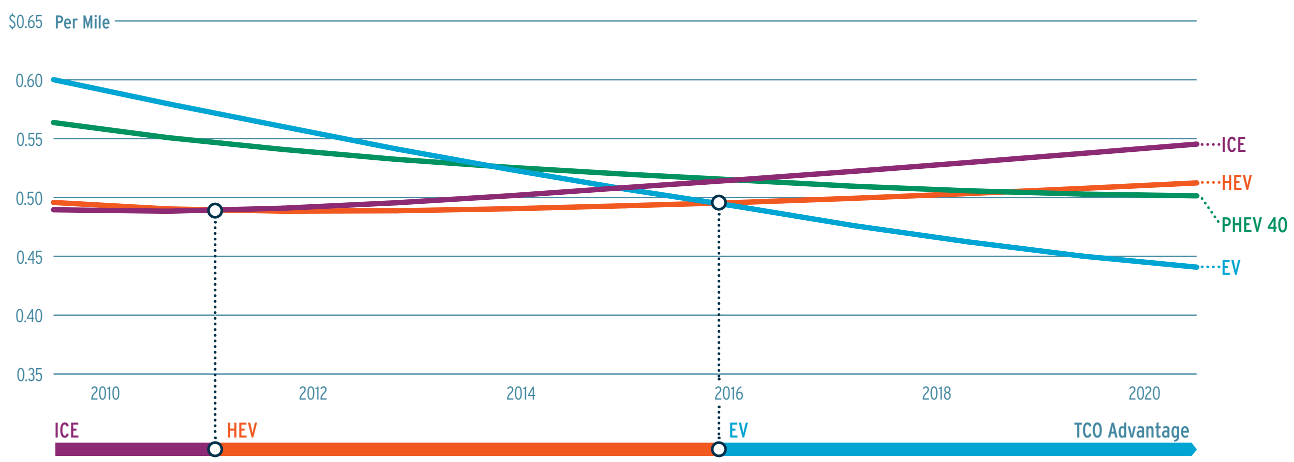
Central Charger Depot Bank · Public Charger · Fast Charger · Home Charger

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.

FIGURE 3DD

2010-2020 xEV Total Cost of Ownership



Vehicle Specifications

ICE	2010	2020
Base Drivetrain	6.7L Diesel / Auto	6.7L Diesel / Auto
Base Engine Cost	$5,500	$5,225
Base Transmission Cost	$4,500	$4,275
Exhaust System Cost	$2,500	$2,375
Fuel System Cost	$2,000	$1,900
Mandated Fuel Efficiency Improvements ($/% of MPG increase)	$43	$86
Fuel Economy	10 MPG	13 MPG

PHEV-40	2010	2020
Electric Range	40 mi	40 mi
Battery Cost	$660	$358
Battery Size	12 kWh	12 kWh
PHEV-40 Battery Life	150,000 mi	150,000 mi
Electric Motor Cost	$3,713	$2,025
Inverter Cost	$6,075	$3,375
Charger Size	6.6 kW	6.6 kW
On-Board Charger Cost	$1,733	$1,584

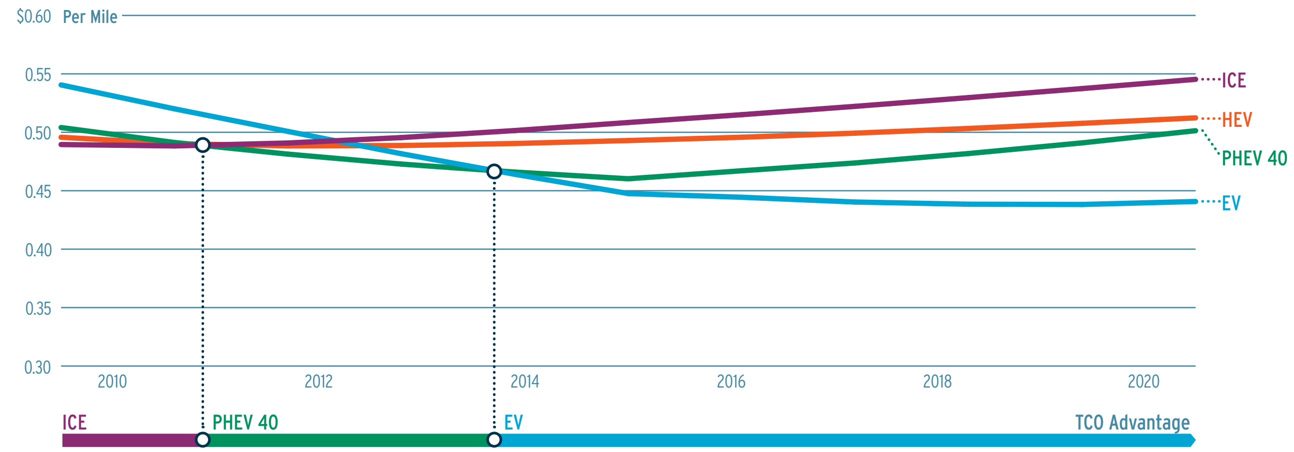
HEV	2010	2020
Battery Cost	1,440	780
Battery Size	5 kWh	5 kWh
HEV Battery Life	200,000 mi	200,000 mi
Electric Motor Cost	$2,888	$1,575
Inverter Cost	$4,725	$2,625

EV-100	2010	2020
Battery Cost	$720 /kWh	$390 /kWh
Battery Size	65 kWh	65 kWh
EV Battery Life	125,000 mi	125,000 mi
CD Range Efficiency	1.5 mi/kWh	1.8 mi/kWh
Electric Motor Cost	$3,713	$2,025
Inverter Cost	$6,075	$3,375
Charger Size	10 kW	10 kW
Onboard Charger Cost	$2,625	$1,800
Single Speed Transmission Cost	$1,800	$1,710

Source: PRTM Analysis

FIGURE 3EE

2010-2020 xEV Total Cost of Ownership Optimized with Incentives



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.

CHAPTER 3.5

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 shows that the attractiveness of GEVs to most fleet operators would be relatively low if no changes were made to the operating model and without monetary incentives. However, if the operations and vehicles are optimized for fleet applications and an incentive structure similar to the current passenger car structure is put in place for all target fleet vehicle segments, the attractiveness of GEVs increases significantly. In this scenario, the commercial segments have a TCO that is either neutral or significantly positive. In addition, the switching difficulty is expected to be reduced significantly in this scenario due to improved access to infrastructure.

The impact of this increase in adoption attractiveness will be an increase in overall adoption rate. As with most new technologies, GEV adoption in fleet applications is likely to follow an S-Curve adoption pattern. Uptake is slow at first but reaches an inflection point at which adoption begins to increase rapidly before reaching a natural steady state. Vehicle technology adoption in fleets tends to be fairly slow when not driven by regulatory changes due to fleet focus on minimizing operating costs and maximizing vehicle up-time. Given this, it is unlikely that any significant number of fleet operators would commit to investing in GEV technology in 2015 if adoption attractiveness is low. Very likely, demand would be limited to niche sub-segments and technical pilots, keeping sales for GEVs at approximately 1 to 2 percent of the targeted fleet segment annual sales in 2015. In this scenario, annual GEV sales would likely be less than 30,000 units in 2015 with a 2015 GEV parc of less than 50,000 vehicles.

However, in the scenario where the adoption attractiveness becomes medium or high for most segments 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.

FIGURE 3FF

2015 GEV Attractiveness - Base Case

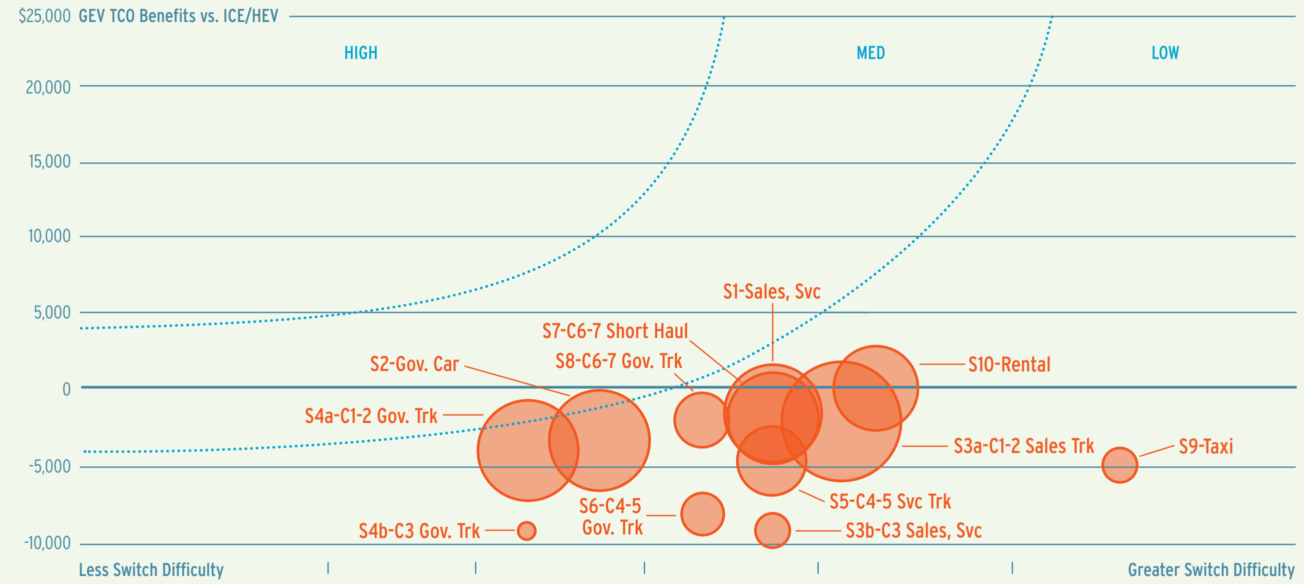
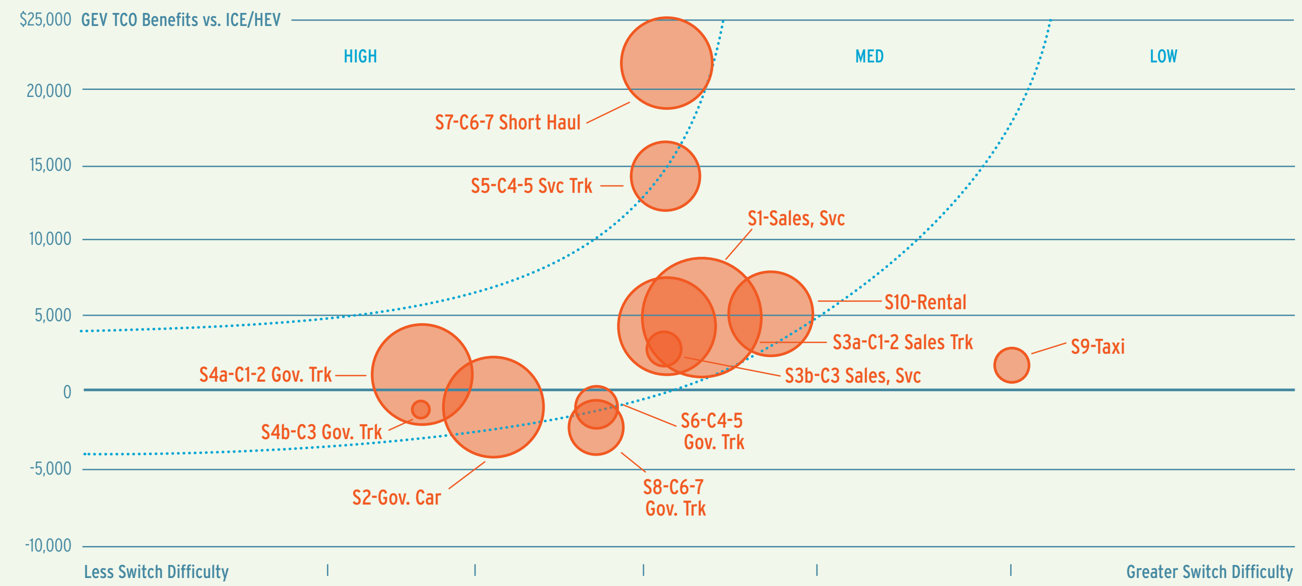


FIGURE 3GG

2015 GEV Attractiveness - Optimized + Incentives



Note: This analysis did not assume that purchase incentives would be available to government agencies. However, policy changes, such as making all tax credits transferable, would make it possible for public sector entities to take advantage of incentives and could increase the uptake of GEVs above the levels envisioned by this report.

Source: PRTM Analysis

PART FOUR

Policy Recommendations

4.1 FLEET MICROSYSTEMS

4.2 OTHER POLICIES

THE UNITED STATES CAPITOL BUILDING 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.)

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.

1 DOE, Fuel Eocnomy.gov, Federal Tax Credits for Hybrids, available online at http://www.fueleconomy.gov/feg/tax_hybrid.shtml
2 *Id.*
3 *Id.*

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 supported 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.

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 $5,000 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 CO_2 emissions in the transport 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 EV 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 CO_2 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. Beginning in 2016, the value of the credits should decline in a linear fashion each year before reaching zero in 2020.

4 ARRA, Section 1141
5 DOE, EERE, Alternative Fuels and Advanced Vehicles Data Center, available online at http://www.afdc.energy.gov/afdc/laws/law/CA/8161

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 owner's 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. Specifically, the law allowed 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 both 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 improving air quality. The expanded use of CREBs should include the purchase and installation of charging infrastructure only, not the creation of competitive energy companies.

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. Expenses 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 to include upgrades performed by a utility and the facility owner to support vehicle charging activities whose costs are charged by the utility Finally, Congress should increase the limit of the tax credit for fleet operators who are installing capacity to charge large numbers of GEVs subject to the table below.

10 – 25 vehicles....................................$125,000
26 –100 vehicles.................................$300,000
100 + vehicles......................................$600,000

Policy Recommendation

Allow immediate expensing of GEV purchases and supporting infrastructure 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 company'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 $680 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 $333 in less 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.[6] 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.

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

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 taxpaying 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 resolve 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.

Vehicles 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.

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.

Policy Recommendation

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.

HEVs are well suited for use by fleets that engage in urban stop and go driving, because such vehicles lose substantial energy as heat in the braking process that can be captured, stored, and reused. Delivery vehicles, public transport vehicles and other heavy vehicles that drive regular urban routes are prime candidates for hybridization, and today's costs for HEV in these sectors could provide near-term opportunities for adoption. Hybrid vehicles can not only achieve substantial saving of fuel, but also reduce tailpipe emissions of nitrous oxide, particulate matter, and carbon dioxide, each an important benefit in their own right. Yet, from the Electrification Coalition's perspective, what may be most attractive about these vehicles is their ability to expand the size of the market for lithium-ion battery cells, large-format batteries, and their component parts. 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.

FIGURE 4A

Expired Credit for Demonstrated Fuel Economy Gains

VEHICLE WEIGHT	MAX FOR 30% FE INCREASE	MAX FOR 40% FE INCREASE	MAX FOR 50% FE INCREASE
8,501-14,000 lbs	$1,500	$2,250	$3,000
14,001-26,000 lbs	$3,000	$4,500	$6,000
> 26,000 lbs	$6,000	$9,000	$12,000

FIGURE 4B

Proposed Maximum Credit Available for Demonstrated Fuel Economy Gains

VEHICLE WEIGHT	20% GAIN	30% GAIN	40% GAIN	50% GAIN
8,500-14,000 lbs	n/a	$3,000	$4,500	$6,000
14,001-26,000 lbs	n/a	$3,000	$9,000	$12,000
26,001-33,000 lbs	n/a	$12,000	$18,000	$24,000
> 33,000 lbs	$10,000	$20,000	$24,000	$24,000

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 PHEV 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 firming 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 underestimate its value: a market for secondary uses of automotive-grade batteries cannot develop until there are used batteries, but there will not be a large supply of used batteries for several years. It is, therefore, difficult for the non-expert, in particular, to estimate the residual value of the battery in a newly purchased vehicle. By immediately guaranteeing the residual value of used batteries at between 60 and 80 percent of their expected value, the government would effectively be offering an incentive to purchasers of PHEVs and EVs while likely costing the government little if anything.

The Department of Energy should establish a program through which purchasers of vehicles with large-format automotive-grade batteries will be guaranteed a 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 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.

Reinsurance Risk Mitigation

To promote the development of a private market to guarantee a minimum residual value of automotive-grade batteries, as an alternative or supplement to a direct government guarantee, the EC proposes the establishment of a tax credit to offset 33 percent of losses incurred by insurers or reinsurers who insure or reinsure the residual value of automotive-grade batteries. The tax credit would require that an insurer insure batteries that were purchased in a new vehicle, and which remained in the vehicle until the sale that triggers the guarantee, but is transferable to subsequent owners of the vehicle. As with the proposal that the government guarantee batteries' residual value, the insured battery also must be intact for the guarantee to be valid.

By providing incentive to the market to guarantee the residual value of used batteries at between 60 and 80 percent of their expected value, the government would effectively be offering an incentive to purchasers of PHEVs and EVs while likely costing the government little if anything.

Policy Recommendation

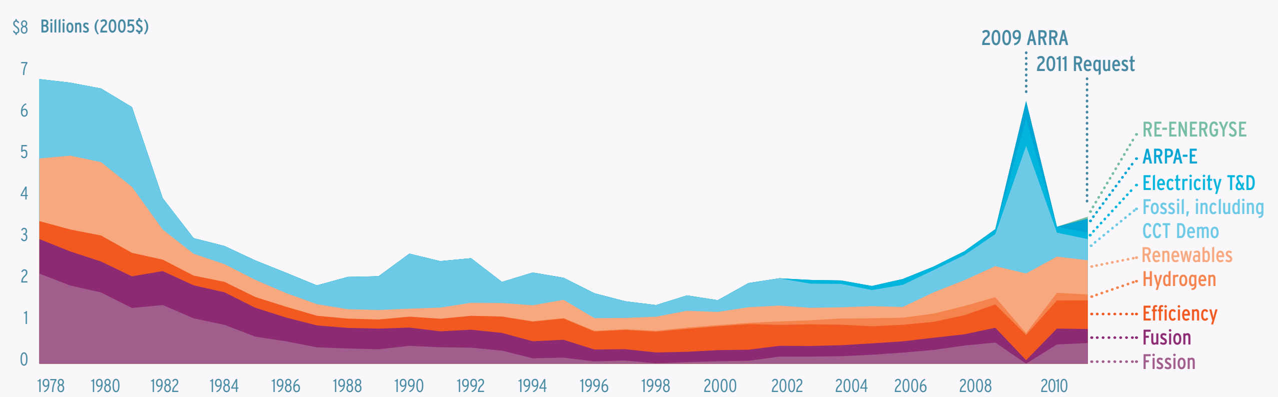
Increase federal investment in advanced battery research and development.

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

7 EC, PRTM interviews.

FIGURE 4C

U.S. DOE Spending on Energy Research and Development



Source: Gallagher, K.S. and L.D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy, John F. Kennedy School of Government, Harvard University, March 22, 2010.

After the energy crisis of 1973, U.S. energy R&D soared from approximately $4 billion annually to $14 billion, with public-sector investment peaking at just under $8 billion and private sector investment topping out at nearly $6 billion. By 2004, total funding had fallen closer to $5 billion. Despite a steady energy-related R&D spending increase in recent years, and a temporary spike facilitated by the American Recovery and Reinvestment Act of 2009, overall levels of government spending are still much lower than they were 30 years ago. (See Figure 4C)

The existing group of lithium-ion battery chemistries will be used in the early suite of GEV offerings to enter the market. Yet scientists are continuing to explore the frontiers of materials science to develop the next generation of batteries, promising better performance, life, and cost. New chemistries that incorporate high-capacity positive electrode materials, alloy electrodes, and electrolytes that are stable at five volts, are ultimately expected to outperform today's available chemistries. The International Energy Agency specifically highlighted a need for continued innovative energy storage research support in its 2009 Electric and Plug-in Hybrid Electric Vehicles Technology Roadmap and reiterated its importance in its 2010 report, Global Gaps in Clean Energy RD&D.

Policy Recommendation

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

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 emissions and performance requirements. In other words, for trucks weighing more than 10,000 lbs., the engines are regulated independently and separately from the vehicle, unlike smaller vehicles where emissions are regulated at the tailpipe. 1One component of emission requirements is that engines must meet certain durability and performance metrics. For example, heavy-duty vehicle engines must be warranted for 10 years and 185,000 miles. 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 PHEV 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 PHEV 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.

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 reduce their fleet fuel consumption by 2 percentage points annually from 2005 to 2015 (a 20 percent reduction). It also directed agencies 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 in E.O. 13423 to reduce fuel consumption by 2 percent annually through 2020 as well. It left the PHEV purchase requirement in E.O. 13423 intact.

The federal government can play a critical role in terms of driving scale throughout the GEV production supply chain. By placing large orders that will turn over regional federal fleets, the government can contribute 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.

Section 30D of the U.S. tax code allow purchasers to receive a tax credit of between $2,500 and $7,500 for a plug-in vehicle with a battery whose capacity exceeds 4 kWh. The size of the tax credit is dependent on the size of the battery. As currently written, it appears that a vehicle may not qualify for the credit if the battery is not purchased with the vehicle and the owner of the vehicle does not own the battery. Because consumers who lease a battery will effectively pay for it even if they do not own it, Congress should clarify the tax code so that purchasers of GEVs who lease a battery (or the right to use a battery owned by the lessor) at the time of purchase are eligible for the tax credit, so long as the battery is physically installed in the vehicle at the time of original purchase.

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.

By replacing petroleum as the dominant transportation fuel, electrification of transportation represents an opportunity for the United States to fundamentally alter the energy security dynamic. A transportation sector largely delinked from oil would isolate the United States from price volatility while increasing investment in domestic energy resources and electrical infrastructure. Electricity is generated from a diverse mix of largely domestic fuels, retail prices are extremely stable, and the network of infrastructure largely already exists.

An impressive array of automakers will introduce the first wave of grid-enabled vehicles to American consumers in 2010 and 2011. These vehicles represent important progress and the successful collaboration of multiple private and public sector entities. But to capitalize on the full economic, employment, and security potential of electrification, penetration of these vehicles will be required at a speed and level not currently projected in typical forecasts. Therefore, more coordination and focus will be required.

The most important challenges constraining the growth of the market for grid-enabled vehicles will largely be the cost and range associated with the first generation of large-format automotive batteries. Costs have already fallen significantly in recent years as manufacturers move from pilot phase projects to market offerings. However, increased volume in battery manufacturing and electric component supply chains will be required to drive costs down to levels that are compelling for mainstream consumers. At the same time, technical advancement down the learning curve can increase the performance of batteries, reducing weight and increasing range.

While electrification of the light-duty, personal-use passenger vehicle market is the most important long-term objective for increased energy security, the early development of the GEV industry will benefit from a more diverse market. Particularly during the period from 2011 to 2015, commercial and government vehicle fleets could represent a large share of the market for plug-in hybrid and fully electric vehicles. In fact, recent announcements by a host of commercial and government entities suggest that this dynamic is already rapidly emerging.

Commercial and government fleet operators should be well-prepared to address a number of the early challenges constraining adoption of grid-enabled vehicles. 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 in a short timeframe. 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.

Targeted, temporary public policy support can and should play a role in supporting this process. Federal tax credits exist for light-duty vehicles, but there are currently no purchase incentives in place to support adoption of grid-enabled medium- and heavy-duty trucks. This should be rectified. Existing infrastructure tax credits should be expanded and modified so that larger installations qualify for applicable benefits. All federal tax credits should be made transferable so that non-profit and public sector entities can access them and all qualifying credits benefit consumers closer to the point of sale. Finally, the federal government can assist in minimizing risk by facilitating the development of a secondary market for large-format automotive batteries.

The analysis conducted for this report suggests that even a subset of these policies would have a meaningful impact on vehicle penetration rates. Combined with efficient investment allocation by fleet operators, temporary public policy could drive more than 200,000 grid-enabled vehicles into commercial and government fleet applications by 2015. Penetration rates of this magnitude during the early evolution of the GEV industry would have a large impact on battery and electric drivetrain component costs, providing increased certainty for suppliers and reduced costs. In turn, these developments would benefit the broader consumer market and help to speed adoption.

Combined with the recommendations outlined in the original Electrification Roadmap, the Coalition has presented a comprehensive framework for guaranteeing American energy security and economic prosperity in the future. America's leaders understand what is at stake and, as a result, electrification continues to garner strong, bipartisan support. Investments made by the public and private sectors over the coming years could move the United States onto more secure footing. And while additional federal outlays must be carefully weighed against other options in today's fiscal environment, the fact remains that energy status quo is both costly and dangerous. Our leaders must view investments in electrification against the alternative: a nation and an economy at risk.

Top 50 Commercial Fleets

RANK/COMPANY		CONTACT	OWNED	LEASED/MANAGED	CARS	CLASS 1-2	CLASS 3-8	VANS	SUVS	XUV	TOTAL
1	**AT&T** St. Louis, MO	Jerome Webber	100%		7,409	25,300	14,178	24,092	3,249	0	74,228
2	**United Parcel Service (UPS)** Atlanta, GA	Mike Hance	100%		0	4,615	66,165	1,853	0	0	72,633
3	**Verizon** Irving, TX	Jay Olshefski			5,920	20,224	23,035	15,509			64,688
4	**Comcast Corp.** Philadelphia, PA	Bud Reuter	100%		562	13,509	3,252	22,360	475	0	40,158
5	**Federal Express Corp.** Memphis, TN	Russell Musgrove	100%	ARI	377	24,388	11,932				36,697
6	**Pfizer, Inc.** New York, NY	Fred Turco		Wheels 100%	30,000			500	500	500	31,500
7	**Coca-Cola Enterprises** Atlanta, GA	Ary Kay Runyan	100%		10,000	0	9,500	0	0	0	19,500
8	**Qwest Communications** Glendale, AZ	Robin Knuckey	90%	Bank of America 5%; GE Fleet 5%	300	10,000	2,500	6,500	50	0	19,350
9	**PepsiCo, Inc.** Purchase, NY	Pete Silva	92%	GE fleet 8%	756	13,609	3,647	209	766	0	18,987
10	**ServiceMaster** Memphis, TN	Steve Gibson	32%	Wheels 35%; PHH 30%; GE Fleet 3%	1,278	10,496	4,346	40	316	0	16,476
11	**Tyco International** Princeton, NJ	Kevin Reynolds		GE fleet 50%; Wheels 50%	2,278	3,932	6,819	2,250	304	14	15,597
12	**Siemens Shared Services, LLC** Iselin, NJ	Jim McCarthy	1%	Wheels 87%; ARI 12%	5,977	3,099	964	3,395	2,124	0	15,559
13	**Salvation Army** Alexandria, VA	Bob Jones			400	0	5,000	9,600	0	0	15,000
14	**State Farm Mutual Auto Insurance Co.** Bloomington, IL	Dick Malcom	94%	Chrysler financial 4%; Toyota financial 2%	10,952	126	38	3,216	38	6	14,376
15	**Oldcastle Materials Group** Atlanta, GA	Ron Piccolo	85%	PHH; GE Fleet; Donlen	1,223	8,375	3,017	318	507	0	13,440
16	**Cox Enterprises** Atlanta, GA	Mark Leuenberger		ARI; Ge fleet; Wheels	1,352	4,285	1,592	4,502	1,399	0	13,130
17	**Sears Holding Corp.** Hoffman Estates, IL	Tiffany Matthews			200	0	0	11,200	468	0	11,868
18	**Quanta Services** Houston, TX	Butch Christian	15%		100	1,800	8,300	500	300	0	11,000
19	**Xerox Corp.** Rochester, NY	Paula Morrisey		GE fleet 100%	450	175	0	9,750	75	0	10,450
20	**Merck & Co., Inc.** Whitehouse Station, NJ	Scott Lauer		PHH 97%; Wheels 3%	8,558	92	31	1,056	20	233	9,990
21	**United Technologies Corp. (UTC)** Hartford, CT	Patrick McGrath	5%	PHH 95%	2,650	2,425	765	3,276	760	0	9,876
22	**Sanofi-Aventis** Bridgewater, NJ	Suzen Moye		ARI, GE, PHH, Wheels	9,600	0	0	0	0	0	9,600
23	**GlaxoSmithKline** Research Triangle Park, NC	Shirley Collins		PHH 60%; ARi 40%	1,739	27	21	835	4607	1,976	9,205
24	**Genuine Parts Company** Atlanta, GA	Chris Lang	50%	ARI; Donlen; Mike Albert; Suntrust	3,110	5,789	150	0	0	0	9,049
25	**Chevron** San Ramon, CA	Kat Travis	80%	ARI; GE Fleet	3,000	5,000	0	500	500	0	9,000
26	**Aramark Services, Inc.** Philadelphia, PA	Kevin Fisher	30%	GE Fleet 40%; PHH 20%	1,320	2,887	2,220	1,031	1,065	287	8,810
27	**Otis Elevator** Bloomfield, CT	Phil Schreiber		PHH 100%	2,028	2,500	1,100	3,000	100	0	8,728
28	**Interstate Brands Corp.** Kansas City, MO	Steve Long	75%	ARI; LeasePlan	400	7,600	238	400	0	0	8,638
29	**Hewlett-Packard Co.** Anaheim, CA	Jeffrey Hurrell	100%	GE Fleet	3,176	18	0	3,778	1,628	0	8,600
30	**Johnson & Johnson** New Brunswick, NK	Louise Davis-Lopez	32%	GE Fleet 68%	6,558	60	0	635	0	1,264	8,523
31	**Novartis Pharmaceuticals** East Hanover, NJ	Lillian Palmieri		LeasePlan 40%; PHH 60%	4,309	0	0	1,428	2,625	0	8,362
32	**Asplundh Tree Experts** Willow Grove, PA	Steve Toeller			200	4,000	4,000	90	0	0	8,290
33	**American Electric Power** Columbus, OH	Wayne Farley			377	3,993	2,419	989	290	0	8,068
34	**Church of Jesus Christ of Latter Day Saints** Salt Lake City, UT	Michael Simms	100%		6,048	1,387	0	422	36	122	8,015
35	**Dycom Industries, Inc.** Palm Beach, FL	Lois Jacobs									8,000
36	**Advance Auto Parts** Roanoke, VA	Carol Davies		ARI 75%; GE 20%; First Fleet 5%	357	5,461	0	173	1,492	0	7,483
37	**United Rentals** Charlotte, NC	Cathy Crewson	3%	ARI 59%; PHH 14%; Penske 6%; Idealease 16%; Ryder 2%	31	4,816	2,308	159	99	6	7,419
38	**Simplex Grinnell** Boca Raton, FL	Janice Buxton		Wheels 100%							7,400
39	**Johnson Controls** Plymouth, MI	Christy Coyte		LeasePlan 90%; PHH 10%	73	2,194	89	4,797	211	0	7,364
40	**Ecolab, Inc.** St. Paul, MN	Gayle Pratt		LeasePlan 100%	1,522	2,482	12	3,030	264	0	7,310
41	**Farmers Insurance Group** Los Angeles, CA	Mark Walters	98%	Donlen 2%	5,939	57	0	536	608	13	7,153
42	**UtiliX Corp.** Kent, WA	Mike Barry			6	6,900	200	25	0	0	7,131
43	**ExxonMobil Corp.** Fairfax, VA	Judy Cornet	100%		2,750	4,150	0	150	50	0	7,100
44	**ADT Security Services** Boca Raton, FL	Becky Carrasco									7,000
43	**ExxonMobil Corp.** Fairfax, VA	Judy Cornet	100%		2,750	4,150	0	150	50	0	7,100
44	**ADT Security Services** Boca Raton, FL	Becky Carrasco									7,000
45	**Embarq** Overland Park, KS	Kim Povirk	15%	GE fleet 85%	245	0	0	6,724	0	0	6,969
46	**Rollins, Inc.** Atlanta, GA	Paul Youngpeter	1%	Emkay .05%; Enterprise 0.5%; Suntrust 95%; Wheels 3%	667	6,205	9	6	51	0	6,938
47	**Pacific Gas & Electric** Concord, CA	Dave Meisel	82%		414	2,414	3,542	112	424	0	6,906
48	**Abbott** Waukegan, IL	Diane Lopez		PHH 100%	1,553	72	0	2,356	2,819	0	6,800
49	**Crop Protection Services (CPS)** Greeley, CO	Christine Chmiel	12%		137	4,741	1,884	12	15	10	6,799
50	**AstraZeneca Pharmaceuticals** Wilmington, DE	Kim Jamme	100%	Wheels	6,200	0	0	400	0	0	6,600

Source: Fleet Automotive, *2010 Automotive Fleet Factbook*

Available Vehicle Matrix – Passenger Portfolio

MAKE	MODEL	TYPE	DESCRIPTION/CLASS (IF APPLICABLE)	BATTERY CAPACITY	ELECTRIC MOTOR CAPACITY	ELECTRIC DRIVING RANGE	TOP SPEED	PRICE	TARGET INTRO
Audi	e-tron	EV	2 sports car based on the R8	42.4 kWh	230kW	154 mi	124mph	-	1,000 car run with target intro 2012
BAIC	C60	EV	4-door sedan	-	-	-	-	-	2011 China
BMW	MegaCity	EV	2-door coupe	35 kWh	112kW	100 mi	95 mph	-	2013
BYD Auto	e6	EV	4 door crossover	48kWh	75kW	186 mi	87 mph	-	2010 China 2010 Targeted US Launch
BYD Auto	F3DM	PHEV	4-door sedan	17 kWh	-	60 mi	-	$22,000	2009 China
Chery Automobile Co.	S18	EV	4-door compact	20kWh	40kW	93 mi	75 mph	$22,000	Nov 2010 China
Citroën	C-ZERO	EV	4-door compact	16 kWh	47 kW	130 km	81 mph	35,000 euros	Q4 2010 EU
Coda Automotive	CODA Sedan	EV	4-door, mid-size sedan	34kWh	100kW	90-120 mi	85 mph	$45,000	California test fleet mid-2010, public delivery fall 2010
Daimler	Smart ED (Electric Drive)	EV	2-door micro car	17kWh	30 kW	84 mi	62 mph	-	2012
Fiat	500EV	EV	Small car	-	-	-	-	-	2012
Fisker	Karma	PHEV	Luxury 4-door	23kWh	300kW	50 mi	150 mph	$88,000	2011
Fisker	Nina	PHEV	Family sedan	20kWh	-	-	-	Est. $40,000	2012
Ford	C-Max	PHEV	MPV	-	-	-	-	-	2012 US
Ford	Focus	EV	4 door hatchback	23kWh	105kW	100 mi	-	-	2011 US
General Motors	Chevrolet Volt	PHEV	4-door hatchback	16kWh	111kW	40 mi	100 mph	$40,000	Nov 2010 US
General Motors	Opel Ampera	PHEV	4-door hatchback	16kWh	111kW	40 mi	100 mph	-	2011 EU
Honda	EV-N	EV	2-door, 4-seater micro car	-	-	-	-	-	2012
Honda	TBD	PHEV	Mid-size to large vehicle	-	-	-	-	-	2012
Hyundai	Blue On	EV	4-door hatchback	16 kWh	49 kW	87 mi	80 mph	-	Korea second half of 2010, 2012 Globally
Lightning Car Company	GT	EV	2-door coupe	-	300kW	150 mi	125 mph	-	2012 UK
Luxgen	EV+	EV	7-passenger minivan	-	180kW	200 mi (@ 25mph constant)	90mph	-	Late 2010 Taiwan
Mitsubishi	iMiEV	EV	4-door hatchback / sub-compact	16 kWh	47 kW	100 mi	81 mph	Below $30,000	Private sales in Japan Apr 2010, US 2011
Nissan	LEAF	EV	5-seater, 4-door hatchback / compact	24 kWh	80kW	100 mi	> 90 mph	$32,780	US & Asia in fleets & limited areas 2010, globally 2012
Peugeot	iOn	EV	4-door hatchback sub-compact	-	47 kW	93 mi	-	-	End of 2010
Renault	Fluence ZE	EV	4-door sedan	22 kWh	70kW	100 mi	81 mph	"21,300 euros - 26,000 euros (excl. battery) separate battery lease from 79 euros per month"	Israel & Europe first half 2011
Renault	Zoe ZE	EV	Compact coupe	-	60kW	100 mi	135 kph	-	2012 Europe
REVA	NXG	EV	Named for "NeXt Generation", two-seater with a targa roof	-	-	124 mi	81mph	23,000 euros	2013 Europe and India
REVA	NXR	EV	Named for "NeXt Reva", four-seat, three-door hatchback family car	Li-ion	-	99 mi	65mph	14,995 euros	2012 Europe & India
SAIC	Roewe 550	PHEV	4-door sedan	Li-ion battery	-	-	-	-	2012 China
SAIC	Roewe 750	EV	4-door sedan	Li-ion battery	-	-	-	-	2012 China
Tazzari	Zero	EV	2-seater	-	-	88mi	-	$31,000	Mid- 2010 US
Tesla Motors	Roadster	EV	2-seater	56 kWh	248 hp	220 mi	125 mph	Base price $109,000 plus options	Available now
Tesla Motors	Model S	EV	4-door coupe, 7-seat	42 kWh (standard config)	-	150 mi, 230 mi & 300 mi (based on battery option)	130 mph	$57,400	2012 USA & EU
Th!nk	City	EV	City car, 2+2 seating	22kWh	-	112 mi	62 mph	-	"Available in Norway 2012 U.S."
Toyota	Prius Plug-in	PHEV	4-door hatchback	Li-ion batteries	-	12.4-18.6 mi	-	-	2010 to release 500 test fleet cars in Japan, EU & USA, Mass production 2012
Volkswagen	Golf Blue e-motion	EV	4-door hatchback	26.5 kWh	85kW	93 mi.	-	-	500 vehicle test feet in 2011. Launch in 2013.
Volkswagen	E-Up!	EV	2-door mini car	-	60 kW	130km	-	-	2013
Volvo	C30	EV	Two-door, four-seater	24 kWh	-	94 mi	81mph	-	2011
Wheego	LiFe	EV	Two-passenger mini car	30kWh	45kW	100 mi	65mph	$32,995	Q4 2010 US

Available Vehicle Matrix – Commercial Portfolio

MAKE	MODEL	TYPE	DESCRIPTION/CLASS (IF APPLICABLE)	BATTERY CAPACITY	ELECTRIC MOTOR CAPACITY	ELECTRIC DRIVING RANGE	TOP SPEED	PRICE	TARGET INTRO
Boulder Electric Vehicles	Truck	EV	Class 3 Delivery truck	80kWh	80kW	120 mi	65 mph	-	Q2 2010 US
Boulder Electric Vehicles	Truck & WUV	EV	Class 2 van	80 kWh	80kW	200mi	70 mph	-	Q2 2010 US
Bright Automotive	Idea	PHEV	Class 1-2 van	13kWh	n/a	38mi	n/a	n/a	2013-14 US
DesignLine	ECO-Smart I	EV	Bus (42 Passenger)	261.8kWh	240kW	120 mi.	76 kmph	$600-700k more than traditional bus	Available Now
EVI	Medium Duty (MD)Trucks & Walk-In (WI) Vans	EV	Class 4, 5, 6 trucks	99 kWh	Electric motor 150 kW	scalable up to 90 mi.	up to 60 mph	$120K-$180K	Available Now
Electrorides	ZeroTruck	EV	Class 4 truck	50 kWh	100 kW	Up to 75 mi.	60 mph	$130K	Available Now
Ford	Transit Connect	EV	Class 1 Van	28 kWh	98kW	80 mi.	75 mph	n/a	2010
IC Bus (Navistar)	CE Series	PHEV	School Route Bus & Commercial Bus	Li-ion, liquid cooled battery pack	25-80kW	Charge-depleting range 40 mi	n/a	$100K	Available Now
Mercedes-Benz	Vito E-CELL	EV	Van	36kWh	70kW	80 mi	50 mph	-	2011
Modec	Box Van	EV	Class 3 Truck / Van	52-85kWh	70kW	60-100 mi (depending on battery type)	50 mph	-	Available Now - Europe
Navistar	eStar	EV	Class 3 Truck / Van	80kWh	70kW	100mi	50mph	$149,000	Available Now - US
Optare	Solo EV Bus	EV	Bus	80kWh	120kW	60 mi	56 mph	-	Accepting orders
Proterra	EcoRide BE35	EV	Bus (51 passenger)	74kWh	150kW	50 mi	65 mph	-	Available Now
Renault	Kangoo ZE	EV	Compact commercial van	22 kWh	44kW	100 mi	130 kph (81 mph)	20,000 euros (excluding battery) plus battery lease from 79 euros per month	Europe 2011
Sinautec	Ultracap Hybrid Bus	EV	Bus	-	-	3.5mi	35mph	-	Available Now
Smith Electric Vehicles	Edison	EV	Class 2 Van or Bus	40kWh	90kW	100 mi	50 mph	-	Available Now
Smith Electric Vehicles	Newton	EV	Class 4-6 Truck	80kWh	120kW	100 mi	50 mph	-	Available Now

Key to Terms

ACES 2009	American Clean Energy and Security Act of 2009.
Advanced Metering	Advanced 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 capability as well as permit the efficient management of power flows, especially from variable renewable sources.
Ampere	A measure of electrical current which represents a flow of one coulomb of electricity per second.
ARRA 2009	American Recovery and Reinvestment Act of 2009.
Battery-Electric Vehicle (BEV)	A type of electric vehicle (see below) 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. HEVs essentially always 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 cylinder, as opposed to fuel injection, when it is injected 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, driveshafts or axle shafts, U-joints, CV-joints, differential and axles.
EISA 2007	Energy Independence and Security Act of 2007.
Electric Drive Vehicle (xEV)	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.
Electric Vehicle (EV)	A vehicle propelled 100 percent by an electric motor, which forms part of an electric drivetrain. The power comes in the form of current from an on-board storage battery, fuel cell, capacitor, photovoltaic array, or generator.
Electric Vehicle Miles Traveled (EVMT)	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 (E-REV)	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 nears depletion. 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 Vehicle (GEV)	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, using the resulting gas expansion for mechanical energy. Conventional vehicle IC engines use two-stroke or four-stroke combustion cycles, which combust intermittently.
IOC	An oil company that is fully or majority owned by private investors.
Kilowatt (kW)	A unit of power equivalent to 1,000 watts, 1,000 joules per second or about 1.34 horsepower.
Kilowatt-hour (kWh)	A unit of energy or work defined as the amount of energy released if work is done at a constant rate of 1 kW for 1 hour, equivalent to 3.6 megajoules. Commonly used to bill for the delivery of electricity.
Load	The amount of power (sometimes called demand) consumed by a utility system, individual customer, or electric device.
Mild Hybrid	Hybrid systems that only stop the engine during idle (while still running heat, A/C etc.), and instantly start it when the vehicle is required to move, providing efficiency gains in the 5 to 10 percent range.
NOC	An oil company that is fully or majority owned by a national government.
Original equipment manufacturer (OEM)	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.
Parallel Hybrid	Hybrids that have an IC engine and electric motor that both provide torque to the wheels. In some cases, the IC engine is the predominant drive system with the electric motor operating to add extra power as required. Others can run with just the electric motor driving.
Peak Demand (or Load)	The greatest electricity demand that occurs during a specified period of time.
Plug-In Hybrid 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 IC 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 electronic device that converts direct current (DC) into alternating current (AC) or AC into DC.
Powertrain	See **Drivetrain**.
Residual Battery Value	The value of a battery established by the market after it has completed its primary purpose service life.
Series Hybrid	A vehicle which has an IC engine and electric motor, but only the electric motor provides torque 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 dormant 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

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.

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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.

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