7.0 The Diffusion of Advanced Vehicle Technologies

7.1 Introduction

Since automobiles were introduced over a century ago, thousands of innovations have been introduced to their powertrains, structures, and other vehicle systems. New technologies allow manufacturers to provide vehicles of increasing levels of utility to consumers—better performance, greater efficiency, more features, and greater carrying capacity. Some innovations, such as new structural materials, deliver improved quality or performance, but are otherwise transparent to customers. Others, such as automatic transmissions, require a consumer to become familiar with the new technology and choose to purchase a new vehicle that incorporates it over an existing vehicle that does not.

The potential benefits of advanced technologies are only realized when those technologies are introduced into vehicles available in showrooms, and consumers purchase those advanced technology vehicles, replacing older vehicles in the vehicle fleet. The spread of new technologies depends upon millions of individuals adopting those technologies; the aggregation of these actions leads to the diffusion of these technologies across the market. To assess the benefits of advanced technologies, it is therefore critical to understand how long this diffusion process will take. The purpose of this chapter is to demonstrate empirical evidence on the diffusion of automotive technologies to help calibrate our predictions about future technology adoption, energy consumption, and emissions, and inform the development of effective strategy and policy decisions.

This chapter is divided into four sections, each addressing a theme related to the diffusion of innovations (technologies) in the automotive sector. First, a review of the innovation diffusion literature is provided, focusing on automotive applications. Second, the diffusion of vehicle features is analyzed using evidence from the United States over the past 40 years. Third, the diffusion of entire alternative fuel powertrains is considered, focusing on the case of the iconic Toyota Prius hybrid-electric vehicle (HEV) in the United States. Finally, the projection of future technology adoption to estimate future energy use and emissions impacts is discussed.

7.2 Literature Review

Extensive literature examines the diffusion of innovations: the process by which new ideas, practices, and technologies spread through a population. The following section summarizes the theoretical foundations of the innovation diffusion literature, the modeling approaches used to quantify the diffusion of innovations, and the application of these tools in the automotive context.

7.2.1 The Diffusion of Innovations

The diffusion of innovations commonly follows an S-shaped or logistic pattern over time, giving rise to Rogers’ adopter classifications such as “innovators” and “early adopters.” More specifically, the diffusion of successful innovations follows an S-shaped pattern toward 100% market share; however, most innovations fail. Less successful innovations may stagnate at some lower market share between 0% and 100%, or may experience “boom and bust,” in which the innovation enjoys some initial success before being rejected by adopters.
Rogers (2003) proposes that the rate of adoption of innovations is governed by the following factors:

1. The *relative advantage* of the innovation;
2. The innovation’s *compatibility* with existing systems, values, and behaviors;
3. The *complexity* of adoption and use of the innovation;
4. The *trialability* of the innovation, enabling experimentation prior to adoption; and
5. The extent to which the benefits of the innovation are *observable* to others.

### 7.2.2 Modeling the Diffusion of Innovations

The Bass diffusion model [Bass, 1969] is the foundation for a family of models commonly applied to the diffusion of innovations, generating the commonly observed logistic or S-shaped form. The Bass model distinguishes roles for innovators, commonly interpreted as those who adopt through exposure to advertising, and imitators, usually interpreted as those who adopt as a result of word-of-mouth communication [Sterman, 2000]. Numerous extensions have since been made to the Bass model, including the addition of prices [Robinson and Lakhani 1975], multiple product generations [Norton and Bass, 1987] and dynamic adopter populations [Mahajan and Peterson, 1978].

### 7.2.3 Technology Diffusion in the Automotive Industry

Nakicenovic (1986) discusses the logistic form of the diffusion of technology in a variety of fields and identifies several examples of the diffusion of automotive features. Nakicenovic also discusses differences among varying types of vehicle features, a concept continued here with the differentiation among safety, powertrain, and comfort/convenience features. Nakicenovic cites examples of the time to reach 50% penetration of a new technology, a parameter referred to later in this chapter as “developmental lag time.”

DeCicco (2010) applies regression with a logistic form to feature data available from EPA for front-wheel drive, fuel injection, multivalve engines, and variable valve timing (VVT). The analysis proposes a logistic function and discusses both the steepness parameter of the adoption curve and also the number of years since the “first significant use,” although it is difficult to discern the criteria being used to establish this date. DeCicco also proposes a logistic function within the range of other powertrain technologies as a plausible deployment scenario for HEVs, although the author notes that HEVs will compete with other technologies for incorporation into future vehicle fleets.
Applying generalized diffusion models such as Bass and Gompertz to estimate the future success of advanced powertrains (such as Lamberson (2009) and Cao (2004)) generates widely varying predictions, due to both the inherent difficulty in predicting future technology diffusion and the lack of decision variables in these models. Struben and Sterman (2008) reconcile the process of innovation diffusion with the discrete choice literature, distinguishing between the social exposure through which consumers develop familiarity with new technologies, and the attributes of the technologies that influence consumer choice. This approach has since been applied in a range of contexts, including the diffusion of diesel vehicles in Europe [Zhang, 2008] and the diffusion of HEVs in the United States [Keith, 2012]. For a detailed review of HEV and electric vehicle (EV) diffusion and consumer choice studies, see Al-Alawi and Bradley (2013).

Consumer behavior is not the only factor to consider. The supply side of the automotive product development cycle also places limitations on the speed at which innovations can be introduced into new vehicles. First, the complexity of modern automobiles means that the design and engineering process for a single product takes years. According to Clark and Fujimoto (1991) and Ellison et al. (1995), U.S. and European automakers reduced overall product lead-time by nearly a year between the 1970s and 1990s, but still stood between four and five years as of publication. While this has been further reduced, the National Highway Transportation Safety Administration (NHTSA) continues to note lead time as an issue of concern with regard to fuel economy standards [NHTSA, 2012].

Additionally, most automotive manufacturers design and produce large portfolios of products, not just a single vehicle. In order to maximize the efficiency of its engineering staff, manufacturers will typically stagger major vehicle redesigns over approximately five years. Plotkin et al. (2013) suggest that this phasing means that an automotive manufacturer needs 8–10 years to introduce an innovation over its entire product line. Such phasing presents a “floor” in the ability to bring new innovations to market, regardless of their appeal to consumers or other potential constraints such as intellectual property restrictions or material shortages. All of these factors tend to place dampers on the adoption process, contributing to the characteristic S-shaped curve.

7.3 Adoption of Features

The technological changes to vehicles over the past 100 years vary widely in magnitude. Many new design tools, fabrication techniques, and materials are transparent to purchasers, delivering incremental improvements in weight, strength, or cost but otherwise remaining undetected by typical consumers. Other changes, such as switching from gasoline to electric power, are so complex that purchasers may consider them a different class of vehicle.

This section examines a specific set of technologies: “features” that manufacturers market to consumers as options on new vehicles or advertise as offering improved functionality. A complete discussion of these results is available in Zoepf (2012).
7.3.1 Regression Analysis of Feature Adoption Rates

The fraction of consumers adopting a feature (known as the take rate of a feature) in year \( t \) was modeled by using least-squares regression to fit market share data to a logistic curve of the following form:

\[
\text{Take Rate}(t) = \frac{\text{Limit}}{1 + ae^{-\beta t}}
\]

Regressions were performed on 35 individual features of passenger cars in the United States, and then secondary regression is performed on two parameters identified from the primary regressions: Maximum Growth Rate and Developmental Lag Time, as shown in Figure 7.1 below.

![Figure 7.1 Key parameters of feature adoption](image)

7.3.2 Maximum Growth Rate

The maximum rate at which the take rate of a technology grows is dependent on a variety of factors: consumer demand, producers’ ability to bring the technology to market on its fleet and, in some cases, the influence of regulation. Figure 7.2 examines a histogram of the maximum growth rate of all features divided into the functional categories of safety, powertrain, and comfort/convenience.

Annual growth rates for comfort and convenience features ranged from 0.8% to 11.6% (Mean 3.6%). Powertrain features were generally adopted faster, with maximum growth rates from 2.4%–13.4% (Mean 7.1%). Safety features saw maximum growth rates from 4.0%–23.9% (Mean 13.6%). Thus, on average, safety feature growth rates are approximately double those of powertrain features, which are in turn approximately double those of comfort and convenience features.
These maximum growth rates seem to support the view, espoused by NHTSA (2011) and others, that an average five-year product development cycle is appropriate for modeling the automotive industry. Even technologies with a clear life-saving benefit cannot be deployed much faster than 20% of the new vehicle fleet per year.

### 7.3.3 Developmental Lag Time

The developmental lag time is defined here as the number of years between the appearance of the first production, street-going vehicle to use a technology and the year of inflection point in that technology’s S-curve, as estimated in the primary regression. Figure 7.3 shows an exponential decline in the developmental lag time of features deployed over the past century.

There are a variety of explanations for such a change in the automotive industry. It is theoretically possible that the marked decrease in developmental lag time of features is the result of more stringent consumer expectations resulting from more exposure to new products and features through new media, and a higher level of communication between consumers leading to greater “word-of-mouth” interaction between adopters and potential adopters.

However, improvements in supply side capabilities have likely played a strong role as well. Clark and Fujimoto (1991) and Ellison et al. (1995) highlight that U.S. and European automakers reduced overall product lead-time by nearly a year between the 1970s and 1990s. The resultant increase in product changes allows a manufacturer to incorporate new features into the product mix more quickly. The structure of the automotive industry itself has also changed significantly over this same time period. Ellison et al. (1995) highlight the increased role that suppliers play in the product development process. Increasing reliance on suppliers suggests that intellectual property is distributed more quickly as suppliers are free to market a new technology to multiple manufacturers.
These factors have dramatically changed the competitive landscape. Developmental lag times have been significantly reduced, but remain just under a decade for new vehicles. The regression equations suggest that developmental lag time is halved in approximately every 30 years. This trend suggests that lag time could be five years in 2030. Plotkin et al. (2013) similarly note the possibility that the current eight to ten years of lead time may need to be re-examined.

### 7.4 Adoption of Alternative Fuel Powertrains

In contrast with the diffusion of individual vehicle features, the diffusion of entire alternative fuel vehicle (AFV) powertrains represents an even more complex challenge. While AFV technologies, such as HEVs and EVs, have substantial future potential for sustainable mobility, no AFV technology is clearly superior to the dominant gasoline internal combustion engine (ICE) regime, when cost and performance are taken into account. The diffusion of AFVs is both enabled and impeded by several strongly positive feedbacks, including the accumulation of consumer familiarity from word-of-mouth communication, technological improvements resulting from R&D and learning by doing, economies and scale and scope, the coevolution of complementary assets including refueling infrastructure, and the turnover of the vehicle fleet as seen in Figure 7.4 [Struben and Sterman 2008].

---

**Figure 7.3** Historical phase-in time of all features

![Graph showing historical phase-in time of all features](image-url)
Numerous previous attempts to introduce AFVs into the U.S. automotive fleet have failed, despite optimistic assessments by political leaders, researchers, and technology advocates. The notable exception since 2000 has been the relative success of gasoline hybrid-electric vehicles (HEVs), with more than 2.5 million HEVs sold in the United States to date. Given this experience, the diffusion of HEVs, and the iconic Toyota Prius HEV in particular, is an instructive case study to inform the future potential for AFVs to permeate through the U.S. automotive fleet.

HEVs combine a conventional ICE engine with an electric powertrain to achieve improved fuel economy and reduced greenhouse gas (GHG) emissions, which result from the capture of kinetic energy through regenerative braking, automatic engine stop/start whenever the vehicle is stationary, and the complementary performance attributes of the gasoline engine (long range) and electric motor (low-end torque and energy efficiency). HEVs are not strictly “alternative fueled,” as they refuel from the existing ubiquitous gasoline station infrastructure and generate electricity for the electric motor on-board the vehicle. However, HEVs cost up to $5,000 more than comparable gasoline vehicles [Bandivadekar et al. 2008], and substantially change the driving experience with the introduction of electric drive, making the purchase of an HEV a complex decision for consumers.
The first HEV in the United States was the two-seat Honda Insight introduced in late 1999. The Toyota Prius, introduced in July 2000, with sales growing rapidly after the second-generation Prius was introduced in October 2003, has become the dominant HEV model sold in the United States. By the end of 2012, the Prius family has accounted for more than 50% of the more than 2.5 million HEVs sold in the United States, including recent Prius ‘c’ and ‘v’ variants (Figure 7.5). Further discussion of the diffusion of the Toyota Prius is available in Keith (2012). Today, more than 45 HEVs are available in the United States (not including plug-in hybrid-electric vehicles (PHEVs)) across most market segments.

A range of incentives has been offered by federal, state, and local governments to encourage consumer adoption of HEVs, including income tax credits, sales tax exemptions and priority access to High Occupancy Vehicle (HOV) lanes. For example, the Federal Government’s “New Energy Tax Credits for Hybrids” program provided tax credits of up to $3,150 between 2006 and 2010. The actual credit varied, based on the relative fuel economy of the HEV and the number of HEVs sold by each manufacturer. California’s law that allowed single-occupant hybrid vehicles access to HOV lanes was subsequently valued at approximately $4,000 based on the price of used hybrid vehicles with and without qualifying vehicle stickers [USA Today, 2007]. Retrospective analysis suggests these incentives have been effective at accelerating HEV sales, particularly when the benefit of the incentive is seen up front [Diamond, 2009; Gallagher and Muehlegger, 2011], although evidence of significant incentive for free riding also exists [Gillingham and Kamala, 2012]. High gasoline prices have also been an important incentive for consumers to adopt HEVs, increasing vehicle operating costs and improving the payback on investments in improved fuel economy. The U.S. average price of gasoline rose from $1.33/gallon in January 2000 to $4.11/gallon in July 2008, before settling to $3.38/gallon in December 2012 [EIA, 2012]. It remains to be seen if more recent declines in gasoline prices will continue, and how large an impact they will have on sales of HEVs.

![Historic sales of HEVs in the United States](image)

**Figure 7.5** Historic sales of HEVs in the United States
Even considering these market forces, growing consumer familiarity with HEVs is critical in explaining the observed diffusion of HEVs in the United States [Keith, 2012]. Consumers will only purchase a new and complex technology such as an HEV once they have gained “…enough information about, understanding of, and emotional attachment to a platform (technology) for it to enter their consideration set” [Struben, 2006]. This familiarity accumulates through social exposure to marketing and “word of mouth,” such as conversations with friends, observing the technology in use, and “trialing” the technology, such as taking a ride in a Prius taxi or getting an HEV as a rental car. Marketing is particularly important early in the process of new product launch, providing the external information needed to educate early adopters who then generate word-of-mouth communications. Toyota invested an estimated $300 million marketing the Toyota Prius in the United States between 2000 and 2010 [Kantar Media, 2010], educating consumers about the unique aspects of the Prius’ hybrid-electric powertrain.

The relative success of HEVs in the United States over more than a decade, compared to previous short-lived attempts to introduce AFVs, represents an important reference case to understand the future potential of alternative fuels and vehicle technologies. Even with favorable market conditions, such as high gasoline prices, the availability of government purchase incentives and compatibility with the existing ubiquitous gasoline station infrastructure, the diffusion of HEVs into the U.S. light-duty vehicle fleet has played out over many years, governed by the slow rate of vehicle fleet turnover and the gradual accumulation of consumer familiarity with this new, complex, and expensive technology. Looking forward, the success of HEVs depends not only on consumer acceptance of the HEV platform, but also on competitive pressures from increasingly efficient gasoline vehicles and emerging plug-in electric vehicles (PHEVs).

### 7.4.1 Evidence from the Early Market for Electric Vehicles

The introduction of the Chevrolet Volt PHEV and the Nissan Leaf battery–electric vehicle (BEV) in December 2010 represents the latest attempt to introduce AFVs into the U.S. automotive fleet. As of June 2013, more than 112,000 plug-in electric vehicles (PHEVs and BEVs) had been sold in the United States supported by policies including an income tax credit of up to $7,500 from the federal government and California’s Zero Emissions Vehicle (ZEV) mandate, which compels automakers to sell a prescribed minimum number of EVs.

Opinions are mixed on whether the launch of PHEVs and BEVs into the U.S. market has been successful. Early statements such as Carlos Ghosn’s prediction in 2010 of 500,000 EV sales annual by the Renault-Nissan alliance by the end of 2013, and President Obama’s goal of putting one million EVs on U.S. roads by 2015, only served to raise the bar against which the diffusion of EVs has been judged, leading to unfavorable comparisons. Others, such as MIT’s Technology Review (2013), have suggested that the launch of EVs has succeeded because sales of EVs in the first three years (PHEVs and BEVs) has exceeded the rate at which HEVs were sold during their first three years in the U.S. market in the early 2000s (Figure 7.6).
It is too early to predict whether the early success of EVs in the U.S. market will lead to their sustained diffusion of EVs through the U.S. light-duty fleet in future years. Growing sales of early EV models, and the expanding range of EV models available to consumers (Figure 7.7), are causes for optimism. However, any comparison with the diffusion of HEVs must take into account the market advantages EVs have enjoyed, including: substantial government incentives, high gasoline prices in the early years after their introduction, and consumer familiarity with electric drive resulting from the relative success of HEVs over the past decade. Automakers have been forced to internally subsidize the development and sale of EVs to meet mandated sales targets in California, and some EV models have been acerbically dubbed “compliance cars,” because manufacturers including Chrysler have signaled their intention to only sell the minimum number of vehicles necessary to satisfy their regulatory obligations [Green Car Reports, 2013]. Previous efforts to introduce AFVs, including Compressed Natural Gas (CNG) vehicles in New Zealand and an earlier attempt to introduce EVs in California in the early 2000s, collapsed when government support was removed. The continued success of EVs depends on finding economically and ecologically sustainable markets as well as overcoming perceived barriers to mainstream adoption, including high battery costs and long recharging times.

7.5 Projection of Future Technology Adoption: Fleet Modeling

While it is important to understand the dynamics of technology adoption, it alone does not capture the impact of technology on future fuel consumption. Each year, 10–15 million new vehicles are sold in the United States, but they represent fewer than 10% of the approximately 240 million vehicles on the road. These 240 million vehicles are generally called the “car parc” or “in-use fleet.” The large number of vehicles in use dampens the impact of new technology as new vehicles slowly replace old vehicles that are scrapped.
To understand the dynamics of in-use vehicle turnover and the broader impact of technology adoption, we use a fleet model, which is a generic term for a numeric representation of vehicles on the road, along with the associated age, distance traveled, and other attributes of each vehicle.

The fleet model establishes a baseline by estimating current vehicle stock based on known average fuel economy of the car and light truck fleets, reported annual sales, detailed estimates of Vehicle Kilometers Traveled (VKT), and scrappage rates. Typically a “Business as Usual” or “No Change” scenario will assume that current vehicle attributes do not change in the future, or will continue to change in accordance with recent trends. To estimate future fuel consumption and emissions, the fleet model incorporates estimates of future fuel consumption, which are derived from predicted penetration rates of advanced vehicle technologies such as hybrids and AFVs.

Various research groups have developed fleet models that perform fundamentally similar calculations. Such models include VISION from Argonne National Laboratories or LEAP from the Stockholm Environment Institute. These models are similar in function and structure; the most significant differences that arise from the use of fleet models are in the input assumptions.

Figure 7.8 shows a block diagram representation of these calculations as used in the Sloan Automotive Lab fleet model, first developed by Bandivadekar (2008). More detailed information on the sources of input estimates can be found in Bandivadekar et al. (2008).
7.5.1 Fleet Modeling Conclusions

The fleet model reveals that new technologies, even those that are adopted and deployed quickly, will take more than a decade to have a significant impact on fuel consumption. R. L. Polk finds that the average age of vehicles in the United States has been climbing consistently, with the average age of a vehicle in the United States now standing at 11.4 years. The increasing durability of vehicles counteracts our ability to deploy technology rapidly, as obsolete vehicles remain on the road longer.

Cheah (2010) investigated scenarios incorporating the most aggressive deployments of alternative powertrain vehicles and lightweighting technologies. These aggressive scenarios predict a net savings of fuel of 1,551 billion liters of gasoline by the year 2030, compared to a baseline scenario with unchanging fuel economy. However, even under the aggressive assumptions in this scenario, naturally-aspirated gasoline engines still hold more than a 50% market share more than 16 years into the future as seen in Figure 7.9.
The impact of new technologies is dampened significantly by the slow turnover of the fleet and the longer useful lifetime of new vehicles, meaning the impacts of new technologies are significantly delayed. Even those technologies that are ubiquitous in showrooms may be seen in fewer than half of the vehicles on the road. Predictions of future technology impact in the automotive industry must carefully consider the necessity to replace an enormous volume of vehicles on the road before the technology impact is felt at the pump, oil wells, and the electrical grid.

7.6 Conclusions

The introduction of technology into the automotive fleet can be viewed as a three-phase process, which serves to limit the rate at which new technologies can reduce fuel demand or displace petroleum. Technology must first be brought into a few production vehicles, where consumers can experiment with the new technology. Sales are limited both by consumer willingness to try the technology and automaker capability to produce these vehicles in larger volume. Therefore, only a few percent of new vehicles include the technology.

In the second phase, consumer word-of-mouth communication and advertising drive technology beyond early adopters to mainstream consumers. In parallel, automakers bring the technology into a larger fraction of their product portfolio as it is redesigned, meeting the demands of the growing market. In this phase, a technology may be commonplace in new vehicles. However, it still represents a tiny fraction of the on-road vehicle fleet and its environmental impact remains small.

Figure 7.9 Predicted market share of alternative fuel vehicles using a sample fleet model input scenario
In the last phase of technology introduction, older vehicles that do not include the technology are scrapped and replaced with newer vehicles that do. This phase is largely independent of consumer adoption and supply constraints. The timing of this phase depends on more fundamental issues such as the durability of new cars and macroeconomic factors that may influence the decision to scrap or repair vehicles.

7.6.1 Near-Term Trends in Technology Adoption

These examples of technology adoption in the automotive sector provide a reason for being cautiously optimistic. The time for bringing automotive features to market has been substantially reduced, suggesting that the 8–10 year minimum deployment time may continue to decrease in the future.

Evidence from more expensive, complex technology adoption, such as EVs, suggests that PHEV and BEV sales are growing more quickly than HEV sales despite their greater complexity and price premium. It is too early to tell whether such adoption is the result of latent consumer demand or the presence of substantial federal, state, and manufacturer incentives.

7.6.2 The Influence of Regulation

Fuel economy regulations are often cited as a means of accelerating the deployment of fuel-efficient technology in the marketplace. However, recent work by MacKenzie (2013) failed to identify a significant effect of Corporate Average Fuel Economy (CAFE) regulations in bringing fuel-efficient technology to market faster.

However, MacKenzie also specifically notes that, during a period of increasingly stringent regulation, a technology-forcing effect may well be present. As a result, as newly adopted CAFE standards through 2025 come into effect in the next few years, it may well be possible to observe an uptick in the adoption of technology.

7.6.3 Opportunities to Accelerate Technology Deployment in the Longer Term

The results of this chapter suggest a number of additional mechanisms that may be effective in stimulating technology growth in the automotive sector.

Fuel taxes are a commonly cited way to create an incentive for consumers to purchase fuel-efficient technologies. Fuel taxes, unlike fuel efficiency standards, create an immediate incentive to scrap older vehicles in favor of newer, more efficient models. As a result, fuel taxes act in two ways: first, as an incentive to invest in technology in a new vehicle purchase, and second, to pull forward a decision to scrap an older, less efficient vehicle. One challenge of such regulations is that older vehicles may not actually be scrapped, but rather simply exported to countries with lower fuel costs or laxer regulations. As a result, policy analyses that show increased scrappage should carefully consider whether such vehicles are truly removed from the fleet or simply moved.
While better technologies and more favorable markets are important, so too is the behavioral role of consumer familiarity with emerging AFV technologies in the adoption process. Traditional marketing on television, radio, and in print media is important for introducing new technologies to consumers, but social exposure through word-of-mouth communication is critical subsequently. Interactive opportunities, such as extended test-drives, deployment of vehicles in taxi fleets, and low-cost, flexible leases, provide consumers with the opportunity to experience the novel aspects of AFVs. Understanding the role of consumer familiarity is also important for policy makers. Incentives will be most cost effective in markets in which there is high consumer familiarity with a new technology as a result of prior adoption, and where those consumers have a high willingness to adopt. In markets with low prior adoption of the new technology, efforts to build consumer familiarity, for example, by deploying AFVs in government and taxi fleets, may be more effective initially.

AFVs also face the chicken-and-egg problem of refueling infrastructure coevolution. To overcome this barrier, a common tactic is to incorporate flex-fuel capability. E85 vehicles, for instance, generally can operate on conventional gasoline and PHEVs can be refueled at a gas station when the battery is depleted. While such flexibility offers additional utility to buyers, assessing the actual benefit of such vehicles is complex. How often are they run on each fuel? Early results from a trial of PHEVs by Zoepf et al. (2013) suggest that there can be enormous variation in consumer recharging behavior (see also Chapter 8 of this report). Similarly, it is widely suspected that many E85 flex-fuel vehicles are rarely run on E85. Such evidence means that it is not only necessary to deploy new technology, but to ensure that it is purchased by those who will actually use it.

Bringing new technology to market may also depend on changing vehicle ownership models. Vehicle sharing, short-term rentals, and partial ownership offer the opportunity to expose larger numbers of consumers to new technology quickly, increasing the trialability of these technologies. Such services also offer the added benefit of accumulating the miles traveled by dozens of users onto a small fleet of vehicles, accelerating their turnover. As a result, such services may accelerate both the communication of new technology in the first and second phases of deployment, and the turnover of the fleet in the final phase of deployment.
References


Kantar Media (2010), Hybrid Vehicle Advertising Data.


