

Drive Green 2020: More Hope than Reality?



A Special Report by J.D. Power and Associates
November 2010

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Global Hybrid and Electric Vehicles: More Hope than Reality during the Next Decade

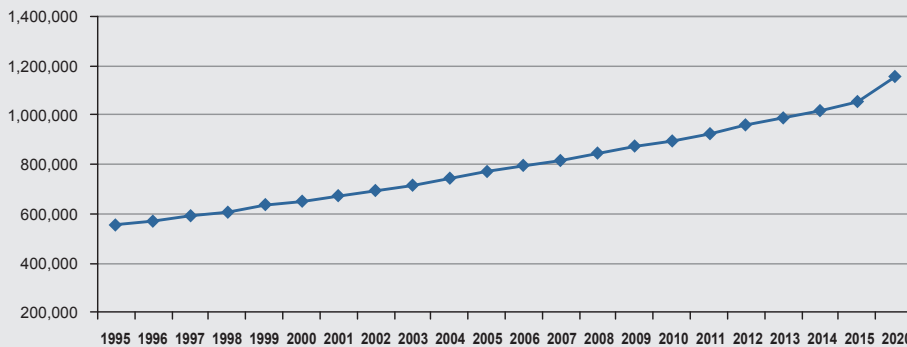
During much of the past decade, the world's major auto shows—from Detroit to Frankfurt, Shanghai to Tokyo—invariably included an environmentally friendly or “green” theme. In almost every instance, the show—and the automakers that displayed their products there—emphasized the importance of developing vehicles that embraced this theme.

The drivers behind this emphasis on green are readily apparent.

In 1995, for the first time, the number of passenger vehicles in operation around the world exceeded 500 million units. The overwhelming majority of these vehicles were sold in economically mature regions, such as North America and Western Europe. With the emergence of a global economy—especially during the past decade—other regions and nations started to add prodigiously to their national vehicle parcs. In 2010, the estimated total global passenger-vehicle parc will reach 896 million units. By 2015, this number is expected to exceed 1 billion vehicles for the first time, and then climb to nearly 1.2 billion vehicles by 2020. Put a different way, it took 95 years to get the first 500 million passenger vehicles in operation simultaneously on a global basis, but it will only take another 20 years from that point to exceed 1 billion passenger vehicles.

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Total Global Units in Operation, 1995-2020



Source: J.D. Power Global Forecasting

While the rapid growth of the global vehicle industry has many benefits—advances in technology and manufacturing processes; creation of ancillary industries; and employment creation, among a host of others—it also has some negative consequences. Two major outcomes include a greater strain on global oil resources and an increasing amount of exhaust emissions from traditional internal combustion engines (ICEs).

Experts disagree about when global oil production will peak (if it hasn't already), but virtually everyone would agree that oil is a finite resource and that at some point in the future it will either run out or, more likely, the energy required to discover and produce new sources of oil will be greater than the energy received from harvesting it. In either case, oil will have run its course as the primary fuel powering the internal combustion engines that drive traditional vehicles.

By 2020, global passenger-vehicle sales are expected to reach 70.9 million units, of which 5.2 million units (7.3% of the total) will feature some type of battery-powered configuration.

The precipitous rise in exhaust emissions, due to the increasing number of vehicles on the road, is probably the more recognizable negative side effect of today's automotive industry growth. Whether or not vehicle exhaust emissions are contributing to global climate change is a hotly debated topic. What is not debatable is that vehicle emissions—in the form of CO₂, smoke, and particulate matter—are a major cause of air pollution, which is detrimental to the environment and to the health of humans, animals, and plants.

Given these challenges, governments and automakers around the world are looking for alternatives to the ICE that limit exhaust emissions and dependence on oil as the principal fuel to power vehicles. Based on the alternative-technology options being developed today, the powertrains of the future will almost certainly rely heavily on some type of battery storage configuration, in which electricity is produced either onboard the vehicle or at designated locations (e.g., home, office, or at public filling stations), and stored in battery packs on the vehicle for use as needed.

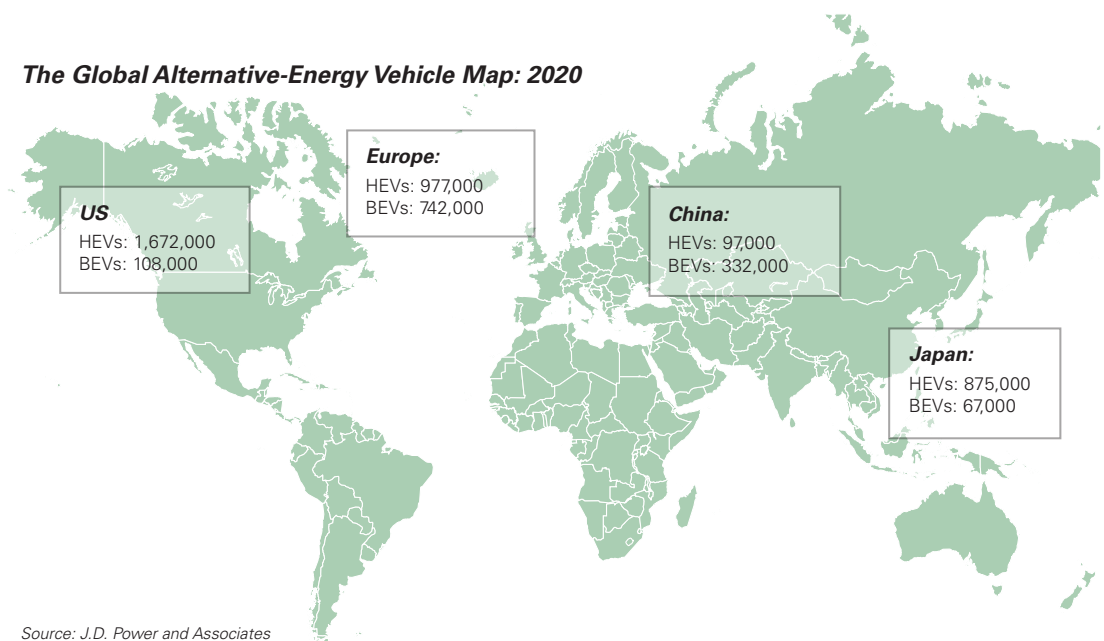
This is not to say that the ICE or other alternatives will not have a role in the future. As the industry moves forward to the electrification of vehicles, diesel and natural gas will continue to play major roles in transportation, as will improvements to the traditional ICE, such as stop-start technologies, cylinder deactivation, and turbo boost, among others.

In 2010, the total number of passenger vehicles sold worldwide is expected to reach 44.7 million units. Of this number, approximately 954,000 vehicles—or 2.2% of the global total—employ some type of battery propulsion system, either hybrid electric or pure battery-driven.

By 2020, global passenger-vehicle sales are expected to reach 70.9 million units, of which 5.2 million units (7.3% of the total) will feature some type of battery-powered configuration.

How the market for alternative-energy vehicles evolves thereafter depends on various inputs. To be sure, in battery-based technologies, much work needs to be done in the areas of battery-life expectancy and driving range; cost reductions in battery production (and, by extension, a decrease in the retail price of hybrid-powered and battery-powered vehicles); infrastructure development to support a mass vehicle fleet that operates on electricity; and consumer acceptance of a technology that is not currently well understood or completely trusted.

The Global Alternative-Energy Vehicle Map: 2020



Source: J.D. Power and Associates

Because J.D. Power and Associates expects that battery-based technologies will lead the charge in the greening of vehicles, this topic represents the primary focus of this report. However, this report will also provide focus on some of the other viable ways to improve the traditional ICE.

As the automotive industry contemplates the future of alternative-energy vehicles, it is with one hopeful eye on the mission of developing a cleaner, cheaper, and sustainable alternative to oil, and another on the technological, economic, and logistical challenges that will need to be overcome to achieve this mission.

A handwritten signature in black ink, appearing to read 'John Humphrey', with a large, stylized initial 'J'.

John Humphrey
Senior Vice President
Global Automotive Division
J.D. Power and Associates

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Objective, Methodology, Definitions

Objective

Estimate demand for alternative-energy vehicles to 2020, including hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs), taking into consideration policy initiatives, market demand drivers, and obstacles such as technological challenges, economic viability, and consumer acceptance issues.

Methodology



Definitions

PV: Passenger Vehicle. J.D. Power and Associates defines passenger vehicles as all passenger cars, SUV/CUVs, and minivan/MPVs. In the United States only, pickup trucks are also considered passenger vehicles.

ICE: Internal Combustion Engine. This is the traditional engine that powers 99.9% of all vehicles on the road today. An ICE uses fuel—typically gasoline, diesel, natural gas, or ethanol, among others—to produce power to drive the vehicle's wheels.

Stop-Start Technology: Technology that shuts down and restarts the internal combustion engine when a vehicle is stopped, as at a traffic stop or in stop-and-go traffic. The stoppage reduces the amount of time the engine spends idling, thus improving fuel economy and reducing exhaust emissions.

Hybrid: Any vehicle that uses a combination of an internal combustion engine and a battery pack to power a vehicle. These include hybrid electric vehicles (HEVs); plug-in hybrid electric vehicles (PHEVs); and extended-range electric vehicles (ER-EVs).

HEV: Hybrid Electric Vehicle. An HEV has an internal combustion engine (ICE), a large battery, and an electric motor to drive a vehicle's wheels. The HEV battery cannot be recharged by plugging into an electric source. The ICE—which typically uses gasoline or diesel as a fuel—can either drive the vehicle's wheels or charge the battery.

PHEV: Plug-In Hybrid Electric Vehicle. A PHEV is an HEV with batteries that can be recharged by plugging into an electric source. A PHEV can run on electric power only for 10-30 miles. A PHEV also includes an ICE that can drive the vehicle's wheels or charge the battery.

ER-EV: Extended-Range Electric Vehicle (e.g., Chevrolet Volt). An ER-EV is an HEV with a battery that powers an electric motor, which drives the vehicle's wheels. The battery is recharged by plugging into an electric source. An ER-EV also has an ICE that acts as a generator only to produce electricity for the battery when it is needed. The ICE does NOT directly drive the vehicle's wheels.

BEV: Battery Electric Vehicle. A BEV typically features a large lithium-ion battery that powers an electric motor, which drives the vehicle's wheels, and does not have an ICE. The BEV battery is recharged by plugging into an electric source. A BEV has a typical driving range of 100-250 miles, depending on battery size and how the vehicle is used.

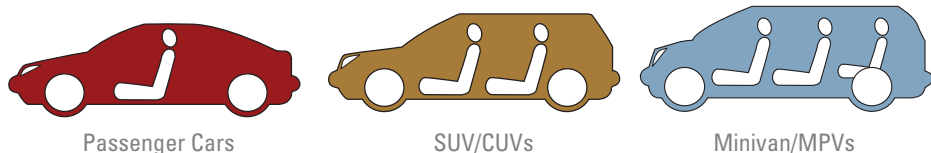
FCEV: Fuel-Cell Electric Vehicle. An FCEV uses hydrogen as a fuel; hydrogen is used in a chemical process that produces electricity, which powers an electric motor that drives the vehicle's wheels. No ICE or battery is required in an FCEV.

Hydrogen Vehicle: A hydrogen vehicle uses a traditional ICE that runs on liquid hydrogen or gasoline, e.g., BMW 7-Series fleet vehicle.

Note: For various currencies referred to in this report, conversions to USD are for reference purposes only.

Passenger Vehicles

The vast majority of HEV and BEV technologies are used in vehicle types included in the Passenger-Vehicle (PV) segment. This report focuses on the PV segment, which is defined by J.D. Power and Associates as including passenger cars, SUV/CUVs, and minivan/MPVs. In the United States only, pickup trucks are also considered passenger vehicles.



Passenger Cars

SUV/CUVs

Minivan/MPVs

Executive Summary



The mass introduction of hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) has gained much attention as a leading solution for reducing global vehicle emissions, improving fuel economy, and reducing the world's dependence on petroleum-based fossil fuels. However, there are significant obstacles that need to be overcome before these objectives can be realized.

Combined global sales of HEVs and BEVs are expected to reach 954,000 units in 2010, or 2.2% of the 44.7 million passenger vehicles projected to be sold globally. While J.D. Power and Associates expects steady growth rates for HEVs and BEVs during the next decade, sales are projected to reach 5.2 million units by 2020, or only 7.3% of the 70.9 million passenger vehicles forecasted to be sold by that year. This is lower than might be expected, given all the attention these technologies have received from governments and the mainstream media around the world.

Interest in HEVs and BEVs is driven by a dramatic reduction in or elimination of tailpipe emissions, and the increased fuel economy of these vehicle types helps reduce the world's dependence on oil. The drawback to these technologies is that fossil fuels (principally oil and coal) are still used to produce the electricity that powers these vehicles, thereby eliminating some of the potential gains. Therefore, it is not clear whether there would be a substantial reduction in emissions by switching to these new powertrain technologies.

In addition to questions about dependence on oil and reduction in emissions, battery packs are prohibitively expensive to manufacture on a large scale, and the disposal of depleted battery packs presents yet another environmental challenge. Perhaps most importantly, there are major hurdles that must be overcome regarding battery-based vehicles to ensure consumer acceptance. These include:

- **Range Anxiety:** Some BEV technologies have a significantly limited driving range, compared with traditional engines.
- **Support Infrastructure:** The current infrastructure to support battery charging is not sufficient to support mass migration to battery-based technology.
- **Power and Performance:** Most HEVs and BEVs cannot deliver the same kind of power and performance as do traditional ICE-powered vehicles.
- **Fuel Economy (\$/km):** In terms of dollars spent per kilometer driven, it is not yet clear whether an electric powertrain may be more efficient than an ICE.
- **Limited Battery Life and Replacement Costs:** Battery packs might need replacement during the vehicle's lifetime, at substantial cost.
- **Overall Cost of Ownership:** It is unclear whether the overall cost of ownership would be lower for green technologies than for ICE-powered vehicles.
- **Extensive Time Required to Recharge Battery Packs:** Most BEV battery packs require long recharging times, compared with the few minutes it takes to refuel an ICE-powered vehicle.

While consumer acceptance of battery-based technologies needs to increase in order to create mass migration to HEVs and BEVs, two other major factors that need to be considered are the global supply of oil and the regulatory policies of the world's leading automotive markets.

If the supply of oil remains steady, as is widely expected, the price of fossil fuels will remain attractive, thus diminishing demand for battery-based vehicle technologies. In this scenario, battery-based vehicles would likely require either continued government subsidies or a major breakthrough in technology to make them affordable and appealing to consumers.

In terms of government regulations, consider the effect that a market such as China might have on global migration to electric vehicles. China is perhaps the only country that has the market scale, political will, and regulatory controls to quickly mandate a mass transition to alternative-energy vehicles. In addition, another unknown is the response that organizations such as OPEC (Organization of Petroleum Exporting Countries) might pursue should a mass transition to electric vehicles occur.

As the world moves toward the adoption of battery-based technologies, improvements to conventional technologies and fuels, such as diesel and natural gas, will serve as a bridge to the greening of the automotive industry. Indeed, J.D. Power expects that the ICE will likely remain the prevalent powertrain technology during the next decade.

Given the challenges that HEVs and BEVs face, and based on J.D. Power's research in automotive markets around the world, it is unlikely that global demand will reach the levels that have been widely predicted for the industry.

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Historical Perspective



It has been 125 years since the first commercialized automotive vehicle was introduced. Since then, economic necessity, technological breakthroughs, new sources of energy, and environmental concerns—combined with government regulations—have been critical in shaping the automobile's evolution. These same factors will play an essential role in driving the transition to alternative-energy vehicles in the future. With this in mind, it is important to provide historical context and to note that many of the challenges faced more than a century ago still exist today.

Dawn of the Automotive Industry

The first vehicle to use an internal combustion engine (ICE) appeared in 1807, when François Isaac de Rivaz developed an engine that burned a combination of hydrogen and oxygen. Thirty years later, Robert Anderson introduced the first battery electric vehicle. The first commercially viable battery electric vehicle followed in 1861 with the introduction of William Morrison's passenger wagon. It wasn't until 1885 that Karl Benz introduced the first affordable and commercially viable ICE-powered automobile in Germany (called the MotorWagen). While both types of vehicles became more widely available, each faced different technological constraints:

- Internal combustion engines were noisy, dirty, had an unpleasant odor, and were prone to mechanical problems. Perhaps their greatest disadvantage was that they had to be cranked to start—a process that required both strength and quick reflexes, as injury was common because the crank tended to kick back while starting.
- Compared with vehicles powered by an internal combustion engine, battery electric automobiles were restricted to shorter driving distances of 25-40 miles because recharging stations were limited. The first battery-powered vehicles were heavier (batteries added significant weight to the vehicle) and initially much slower than their ICE-powered counterparts, and required frequent maintenance.

Alternative Fuels Began to Proliferate

The hybrid electric automobile debuted to positive reviews in 1900 when Ferdinand Porsche displayed his gasoline electric automobile at the Paris Exhibition. However, by 1920, due to their complexity and relatively higher production cost, the hybrid electric powertrain all but vanished as a commercially viable technology.

In the early 1900s, battery electric automobiles were even more common than they are today. By 1918, in the United States alone, there were nearly 50,000 electric automobiles on the road. Nevertheless, due to key technological and logistical developments in the early 1900s, ICE-powered vehicles eclipsed both battery electric and hybrid electric automobiles.

While the power and speed of the ICE showed tremendous promise, the high cost of owning an ICE-powered vehicle and the lack of a widespread fuel-distribution network curbed sales. Moreover, the ICE's cumbersome and potentially dangerous hand crank continued to be an obstacle to the technology's widespread acceptance.

Wider Availability of Petroleum-Based Fuel Drives Sales Growth

One of the major hurdles preventing the extensive adoption of ICEs in the United States was the lack of a steady supply of crude oil. This challenge began to dissipate in 1901 when the first US oil well was drilled, leading to widespread drilling across the country. The easy availability of plentiful oil helped the United States quickly surpass Europe in the production and sale of ICE-powered vehicles.

While anxiety about the availability of fuel for ICE-powered vehicles was alleviated, there were still concerns about how to manage the hand crank. In 1908, a few years after the first oil well was drilled in the United States, Henry Ford introduced the Model T, a relatively inexpensive ICE-powered automobile that could be built at one-fourth the cost of a battery electric vehicle. The Model T proved to be a significant—if not the major—catalyst to the demise of the battery electric vehicle. Three years later, in 1911, Charles Kettering invented the electric starter, which eliminated the need for the troublesome hand crank.

The momentum for ICE-powered vehicles increased. Another major boost to sales of the now-inexpensive and easy-to-operate ICE vehicles was the passage of the Federal Highway Act of 1921, which provided for the construction of a highway infrastructure across the United States.

World War II Refocused Global Interest on Electric Vehicles

During World War II, gasoline for public consumption was rationed, which resulted in yet another surge in alternative powertrains, especially those powered by electricity.

In Great Britain, the availability of plentiful and cheap electricity in the mid-1930s kept the battery electric vehicle industry alive, even before the gasoline shortages of World War II. Germany exempted taxes on battery electric automobiles to promote their use during the same time period.

After World War II, the Tama Electric Powercar became popular in Japan, especially due to the country's severe gasoline shortages. The Tama had an impressive driving range of 150 km (93 miles) and a top speed of nearly 60 km/h (38 mph). However, electric-vehicle production was short-lived, as Tama turned to ICE-powered production in the 1950s when gasoline became more readily available.

Although battery electric vehicles represented a significant share of the global automotive market in the late 1920s and early 1930s, a readily available supply of gasoline after World War II contributed to the nearly 30-year hiatus in the development of battery electric vehicles that followed.

Energy Shortages, Environmental Concerns Lead To a Different Way of Thinking

From post-World War II until the 1970s, ICE engines powered the majority of the world's vehicles. However, fuel shortages experienced in many developed countries in the early 1970s created more public support for fuel alternatives to gasoline. There also was a new and growing concern about the effect of pollution on the environment and on human health in the United States and Europe. Some interesting publications and events triggered new, greener thinking:

- In 1962, Rachel Carson wrote *Silent Spring*, a book that significantly altered public perception toward environmental issues. Carson revealed the hazards of widespread pesticide use to the health of humans and animals. The impact was dramatic, and likely contributed to the establishment of the Environmental Protection Agency in 1970.



The Model T proved to be a significant—if not the major—catalyst to the demise of the battery electric vehicle.

- Six years after *Silent Spring* was published, student groups across Europe began frequent protests, connecting concerns about the environment to state regulatory authority.
- In 1970, an extraordinary session of the Diet, the Japanese parliament, was convened, and the government submitted 14 pollution-related bills for consideration, which were all approved.
- It became so widely acknowledged that ICE emissions were harmful that in May 1969, U Thant, Secretary General of the United Nations, predicted the world had only 10 years to avert environmental disaster if the issue was not addressed.

This shift in attitudes about the perceived threat of emissions to the world's collective well-being helped create some urgency among a majority of countries to investigate and develop alternatives to petroleum-based fuels. In the United States, California led the way in pushing forward a stringent air quality agenda. In 1990, California passed the Zero Emission Vehicle (ZEV) Mandate, requiring 2% of all vehicles sold in that state in 1998 to be ZEVs, and rising to 10% by 2003. The California mandate motivated the US government and US industry to develop cleaner vehicles and alternative-fuel sources. At the same time, some European countries began to focus on clean-diesel vehicles that had much-improved particulate emissions. As a result, some governments have subsequently based taxes on the tailpipe emissions of the vehicle purchased, or raised taxes on petroleum-based fuels.

Conclusion

In the past 20 years, there have been many technological advances related to new sources of energy and a broader variety of powertrains for vehicles, as well as tremendous improvements in fuel economy and commensurate reductions in auto exhaust emissions. Many of these changes can be directly attributed to public concern about the environment, which has led to new government regulations and innovation in vehicle research and development. All of these have been critical in shaping the evolution of automobiles and alternate-energy vehicles.

Some of the larger concerns today with these newer technologies—such as the reduction in the cost of hybrid and electric vehicles, coupled with the need for future technological breakthroughs in terms of battery rate of recharge, driving range, battery life, and recyclability—will be prerequisites for any massive migration to hybrid or electric vehicles. The near future will depend on improving existing technologies, while also experimenting with new technologies that will carry the global community into the next 125 years.

Battery-Based Technologies

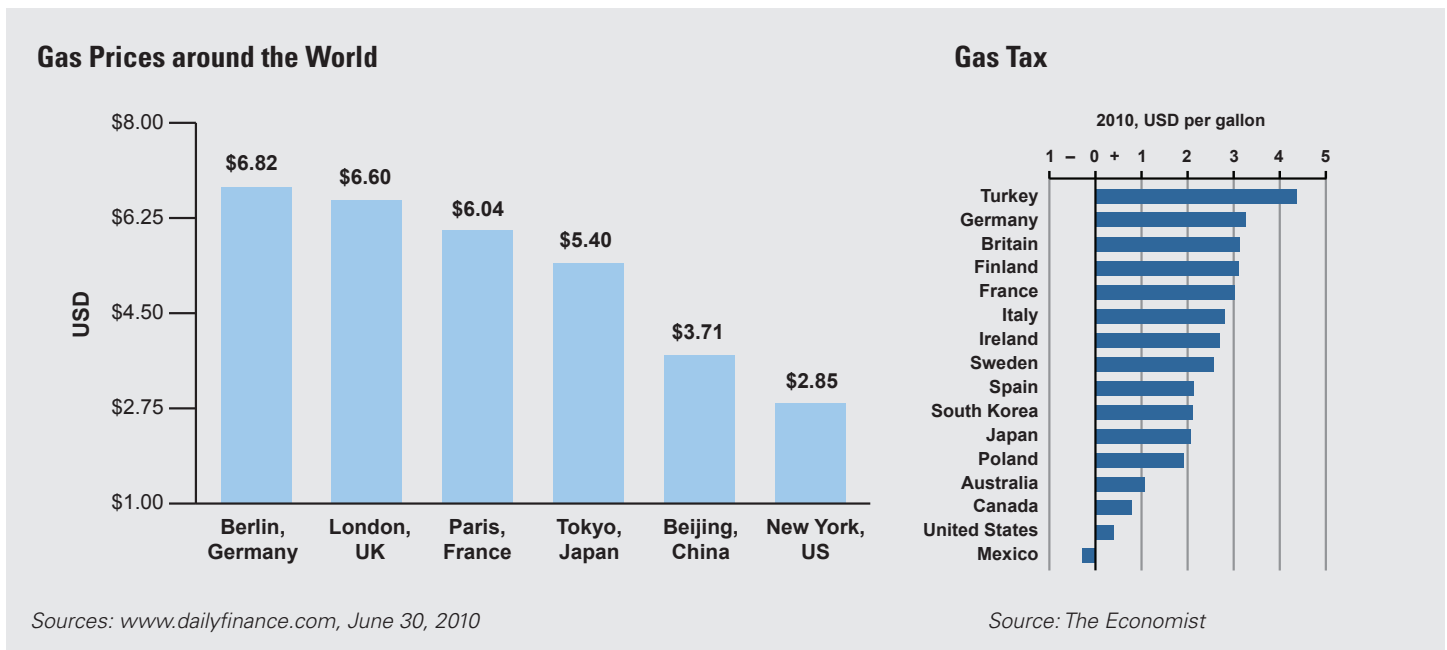
Global Overview

While there is a tremendous amount of positive publicity regarding the environmental benefits associated with hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs), J.D. Power and Associates is significantly less optimistic about the potential for the widespread adoption of these vehicle technologies during the next decade.

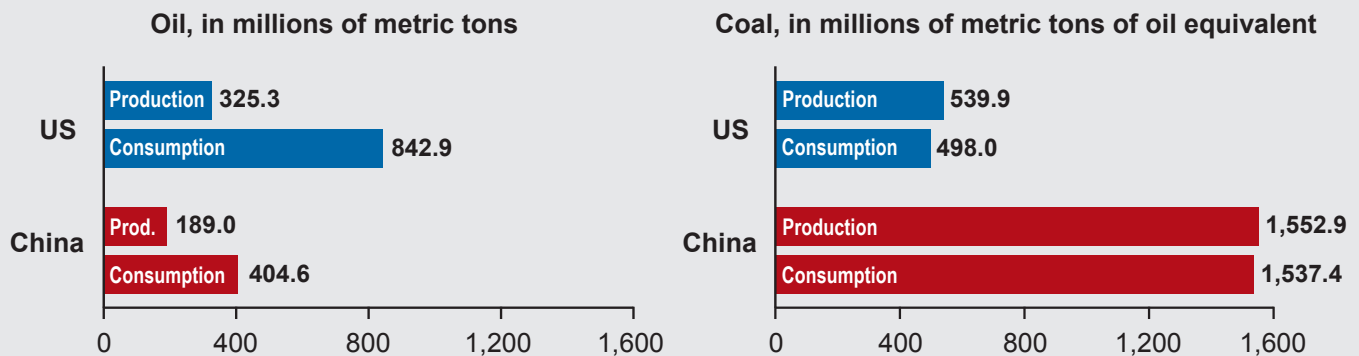
Although few would argue against the goals of reducing emissions, improving fuel economy, and reducing the world's dependence on petroleum-based fossil fuels, there are significant concerns that need to be addressed before these goals can be achieved on a considerable scale.

Perhaps the largest obstacle to be overcome is the availability of inexpensive petroleum-based fuels available in the two largest automotive markets in the world, China and the United States. In 2010, some 22 million passenger vehicles will be sold in these two countries, or 50% of the world total.

At the same time, China and the United States also have among the lowest gasoline prices of the world's largest industrialized nations, and among the lowest taxes on gasoline. In the United States, gasoline is taxed at only \$0.39 per gallon, on average, and the gasoline tax has not been increased in nearly 20 years. In China, oil companies are owned by the government, and gasoline prices are heavily regulated.



Among the most noteworthy of these concerns is the real possibility that a mass conversion to an electrified global automotive fleet might only be transferring the exhaust-emissions problem upstream. Many of the world's electricity-generation plants still depend on burning coal and oil to generate power. As a result, a mass transition to vehicles that depend on electricity (especially BEVs and plug-in electric vehicles, or PHEVs) might only result in changing where exhaust is emitted, rather than decreasing the amount of exhaust emitted.

Domestic Production vs. Consumption, 2009

Sources: International Energy Agency (IEA); IMF; BP Statistical Review

There is perhaps no more relevant example of this than in China. In 2009, China surpassed the United States as the largest vehicle market in the world, and in mid-2010, surpassed the United States as the leading consumer of energy in the world. Today, China is the largest consumer of coal and boasts the world's largest coal reserves. Additionally, the country's leadership has made clear its plans to convert the national automotive fleet to battery-based technologies as quickly as possible. While experts disagree about the effect that mass conversion to electric vehicles will have on emissions, it is possible that there will be little or no net benefit if coal and oil are used to generate the electricity needed to power these vehicles.

Other obstacles to a global mass transition to electric vehicles include:

- Technological hurdles, including the recharging time and life span of battery packs, and an infrastructure to support a conversion to a mass fleet of electric vehicles.
- Consumer acceptance, including willingness to pay a premium for new technologies until critical mass is achieved and prices decrease.
- Economic challenges of creating a sustainable (i.e., profitable) alternative-energy vehicle industry that does not depend on government subsidies or higher taxes.
- Agreement on globally comprehensive, cohesive, and complementary policies that ensure governments and private industry are pursuing similar goals that will drive efficiencies. This might be accomplished through an agreement of members of the United Nations, or of the world's largest vehicle-producing nations.

To understand where the alternative-energy vehicle industry is heading, it is important to understand where the market is today and how it got to this point.

Market

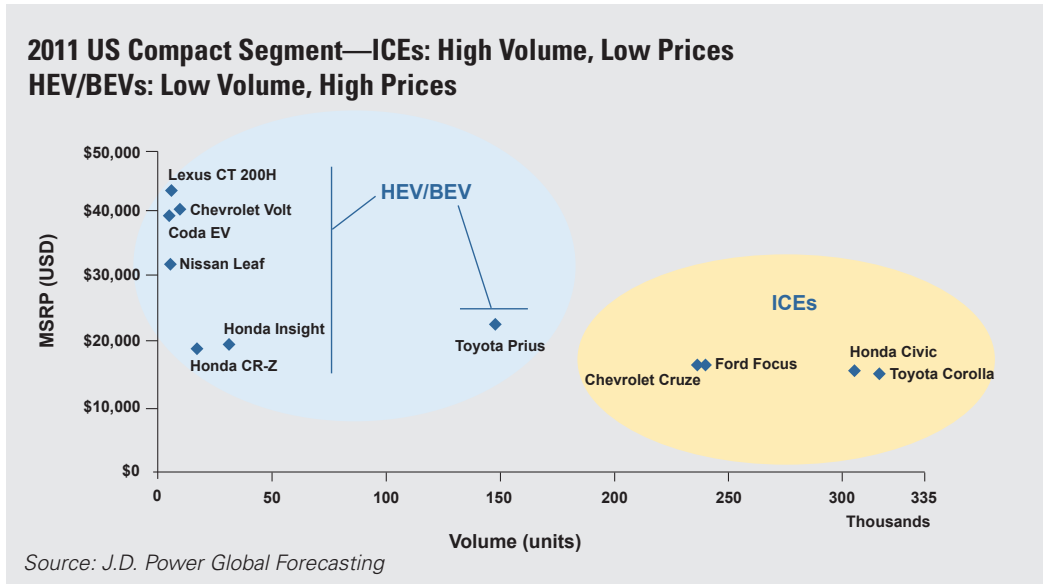
Consumers

Both HEV and BEV technologies currently include a price premium that is most frequently paid by consumers. Compared with a traditional compact vehicle powered by an internal combustion engine (ICE), a comparably sized HEV is typically priced 30%-40% higher, and a BEV is priced 50%-100% higher (depending on the subsidies received).

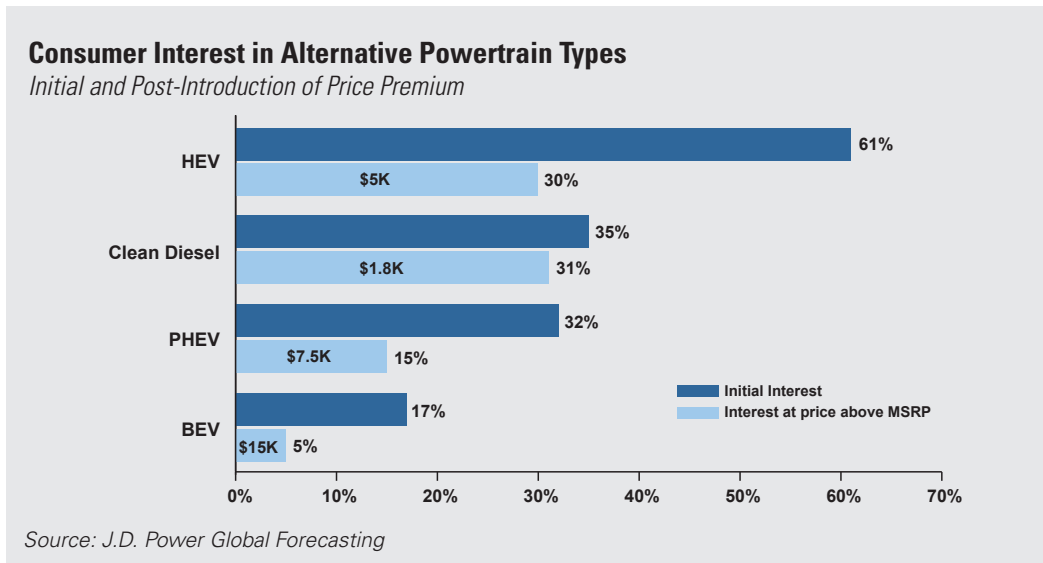
Using the compact car segment in the United States as an example, the forecasted top four best-selling models in 2011 (Toyota Corolla, Honda Civic, Ford Focus, and Chevrolet Cruze) have MSRPs ranging from US \$15,400 to US \$16,200, and projected sales volumes ranging from approximately 240,000 to 315,000 units.

By contrast, in 2011, the best-selling Toyota Prius HEV is expected to have an MSRP of US \$22,800 (37%-40% higher than the other best-selling models in the compact car segment), and sell approximately 145,000 units (100,000 to 170,000 units fewer than the other best-selling models in the same segment).

Moreover, other newer HEV/BEVs in the compact car segment are forecasted to have much lower sales volumes (ranging from 4,000 to 16,000 units) and much higher MSRPs (ranging from US \$19,200 to more than US \$40,000).



J.D. Power research shows that US consumers’ interest in alternative powertrains drops considerably when they are advised of the price premium associated with the purchase of an HEV or BEV. For example, while 61% of consumers surveyed said they were interested in purchasing a hybrid vehicle, only 30% said they were still interested when they learned the price would be US \$5,000 more than that of a comparable ICE-powered vehicle. Additionally, 17% of consumers surveyed initially said they were interested in buying a BEV, but this proportion dropped to 5% after they were advised that the price would be US \$15,000 higher than a traditional ICE-powered vehicle.

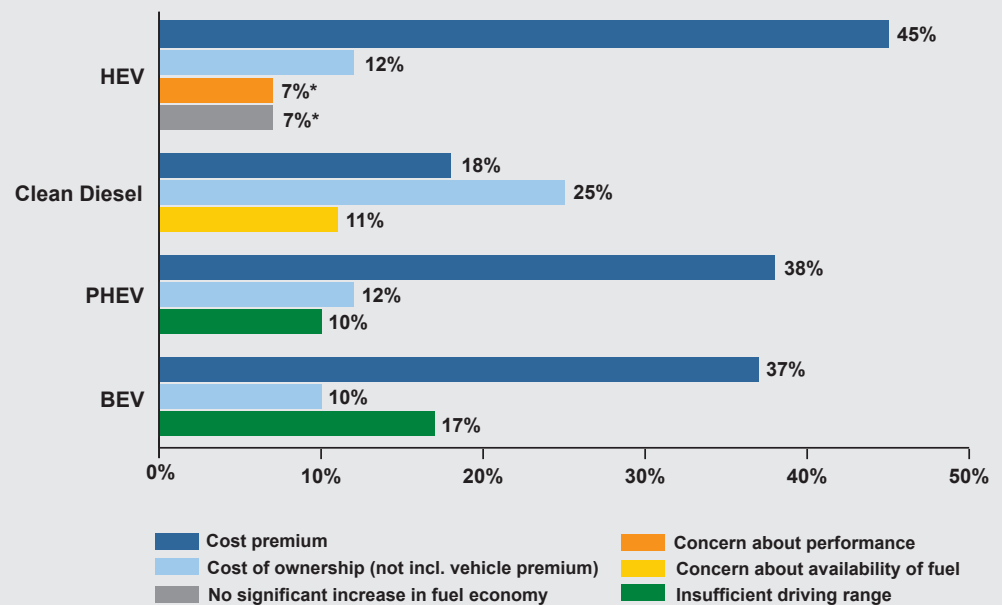


While the price premium of HEVs and BEVs is expected to decrease over time as economies of scale increase, declines of any real significance are not anticipated during the next 5 years. Beyond that time frame, any reductions in price will likely depend largely on technological breakthroughs that reduce the cost of the materials needed to make batteries and increase the life of the battery.

As consumers attempt to minimize the costs and maximize the value of their vehicle purchases, they are likely to assess the total personal cost of their purchase against the projected length of ownership. Currently, studies indicate that the total cost of ownership of green vehicles—either real or perceived—is higher than that for standard gasoline-based ICE vehicles, thus diminishing consumer interest in such vehicles.

Lack of Interest in Alternative Powertrain Types

Top Three Reasons



Source: J.D. Power and Associates Research

While most consumers say they want to create a smaller personal carbon footprint, J.D. Power research shows this consideration carries relatively low weight in the vehicle-purchase decision.

Another element that factors into the purchase decision is the value consumers derive from their purchase vs. the perceived contribution they are making to a cleaner environment and a more sustainable future. While most consumers say they want to create a smaller personal carbon footprint, J.D. Power research shows that, in general, this consideration carries relatively low weight in the vehicle-purchase decision.

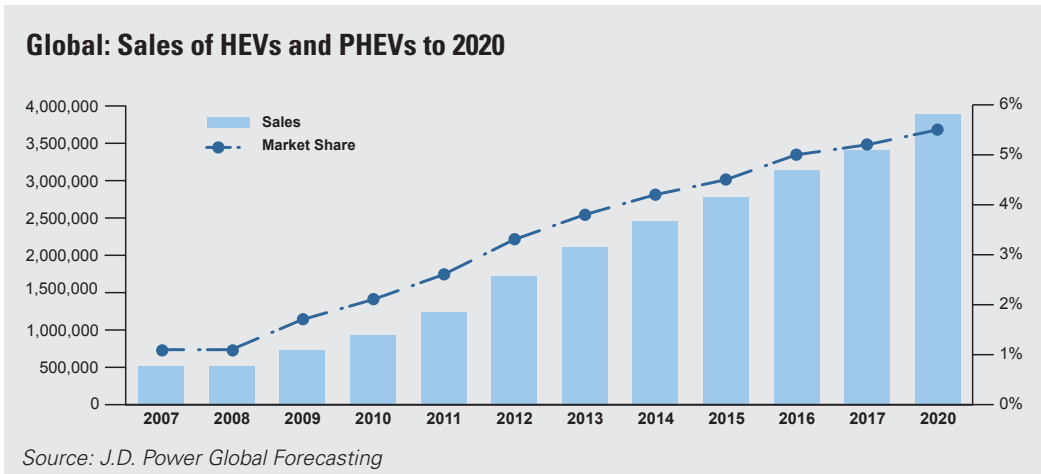
Based on the real and perceived negative financial challenges that alternative-energy vehicles present to consumers—and as long as the price of oil remains relatively stable—it does not seem likely that the growth rate of such battery-based vehicles as HEVs and BEVs will be significant. Automakers will be challenged to convince consumers to invest in these relatively expensive and unproven technologies.

Global Hybrid Passenger-Vehicle Sales Outlook

Global sales of hybrid vehicles—including HEVs, PHEVs, and extended-range electric vehicles (ER-EVs)—are expected to total 934,000 units in 2010, or 2.0% of the 44.7 million passenger vehicles projected to be sold globally.

Nearly 85% of all HEV sales in 2010 are expected to be concentrated in two countries: Japan (446,000 units) and the United States (328,000 units). Sales of the remaining 15% of hybrids (or 140,000 units) will be scattered in small pockets around the world.

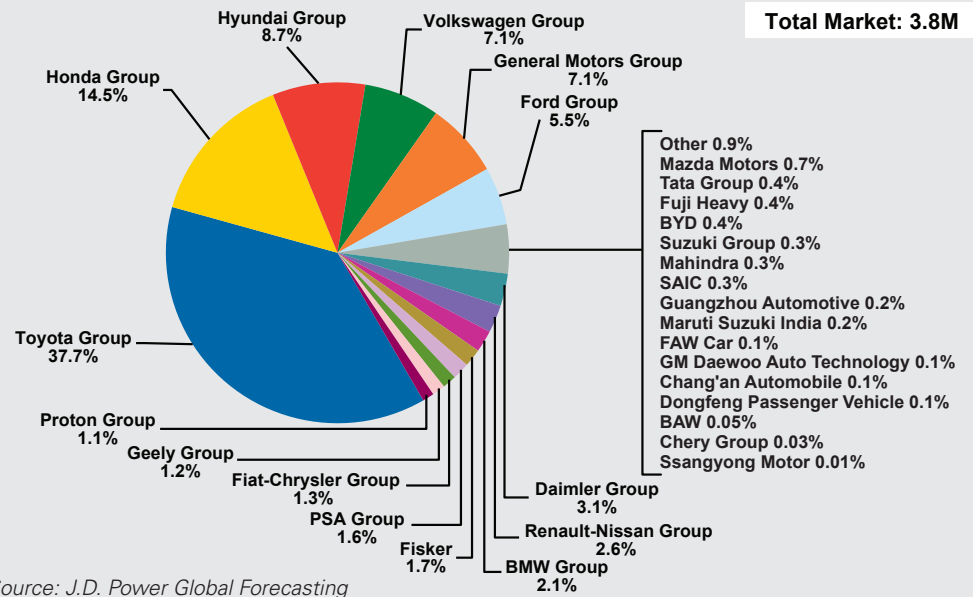
J.D. Power expects the compounded annual growth rate for global HEV sales between 2010 and 2020 to be 13.8%. Still, despite the expected rapid growth rate, sales are projected to be just 3.88 million units in 2020, or only 5.5% of the 70.9 million passenger vehicles to be sold by that year. The United States is forecasted to account for 53% of the global HEV total, followed by Japan (20%) and Europe (16%), while the remaining 11% will be spread among all other countries.



While regional sales of HEVs have been heavily tilted toward the United States and Japan in 2010, HEV sales have been concentrated between two automaker groups: Toyota Group and Honda Group. Toyota-branded vehicles are expected to account for 64% of all HEVs sold globally in 2010, and Honda-branded vehicles are expected to account for nearly 25%. In 2020, J.D. Power expects that three-fourths of the global HEV fleet will be produced by only five manufacturer groups: Toyota Group, Honda Group, Hyundai Group, Volkswagen Group, and General Motors Group.

In 2010, global sales of hybrids and plug-in hybrid electric vehicles are expected to account for just 2.0% of the 44.7 million passenger vehicles projected to be sold globally.

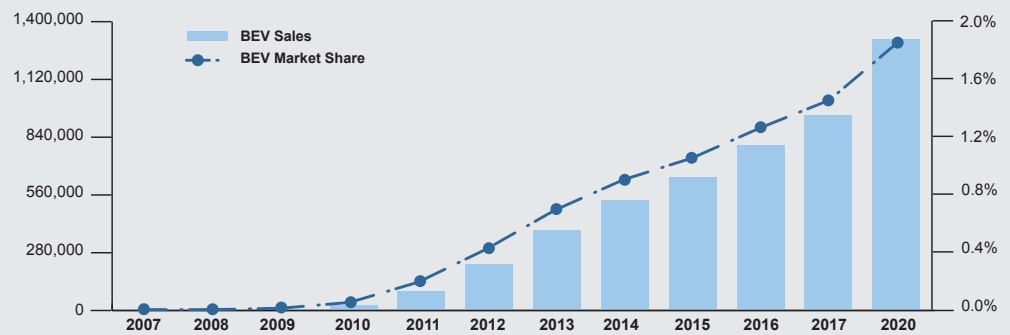
Global: Projected 2020 HEV and PHEV Market Share by Manufacturer Group



BEV Global Passenger-Vehicle Outlook

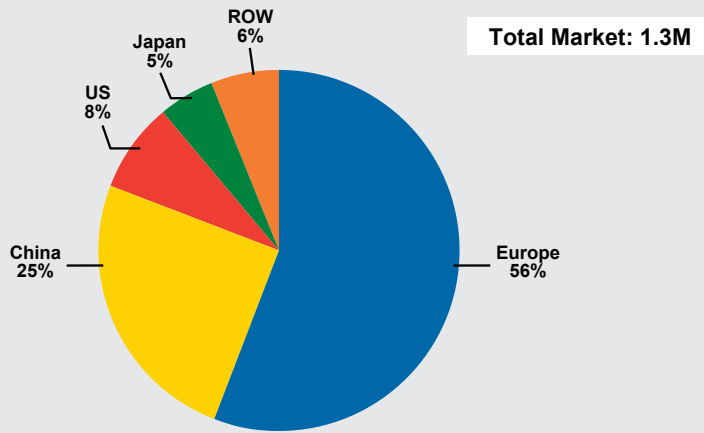
In 2010, sales of BEVs are expected to reach just 20,150 units worldwide. J.D. Power expects BEV sales to increase to nearly 640,000 units by 2015, and then double to 1.31 million units by 2020. While this appears to be rapid growth, projected global BEV sales in 2020 would account for only 1.8% of the 70.9 million passenger vehicles expected to be sold that year.

Global: Sales of BEVs—2007-2020



On a regional basis, Europe is expected to account for 56% of BEV sales by 2020, followed by China (25%), the United States (8%), and Japan (5%). The driving force behind the expected surge in BEV sales in Europe is stricter exhaust-emissions regulations projected to be enforced by the European Union in the next 5 to 10 years. These new regulations will cause diesel share of sales to decrease in Europe, with a commensurate increase in BEV sales. China is also expected to become a significant contender in BEV production, as the Chinese government announced plans in mid-2010 to invest RMB 100 billion (US \$15 billion) in technology and infrastructure development during the next decade.

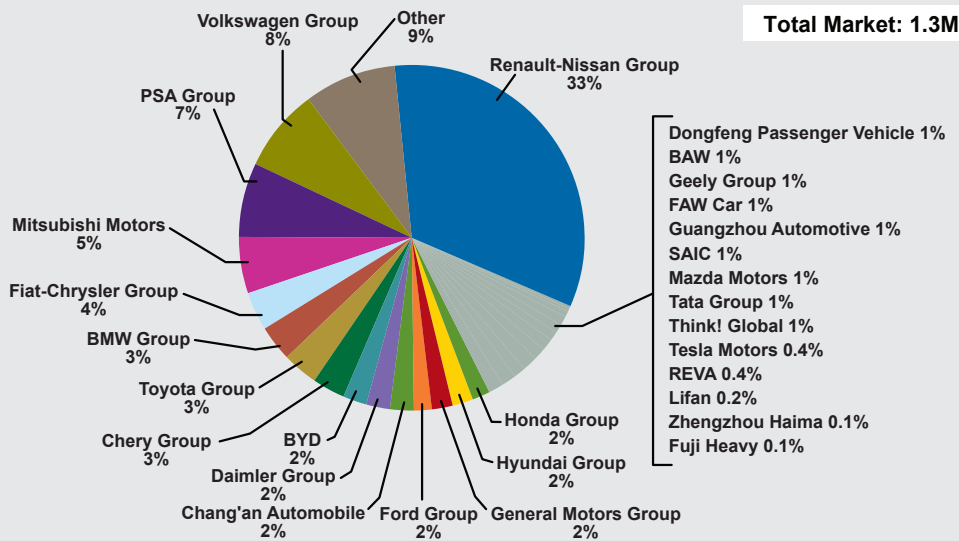
Regional BEV Market Share for 2020



Source: J.D. Power Global Forecasting

More than 30 global vehicle automakers are expected to be manufacturing and selling BEVs by 2020, but only one—the Renault-Nissan Group—is expected to have more than a double-digit share of the global BEV market by that time. Renault-Nissan is forecasted to account for 34% of all BEV sales by 2020, followed by the PSA Group (6.1%) and the Volkswagen Group (6.0%).

Global: Projected 2020 Sales of BEVs



Source: J.D. Power Global Forecasting

Global Regulatory Environment

Based on the various governmental and industry initiatives being pursued in markets around the world, it is clear that there is no global consensus on how to convert from a petroleum-based economy to newer, greener, alternative technologies.

The initial attempt at regulating global exhaust emissions (and climate change) began in 1979 with the first World Climate Conference. However, it wasn't until 1992 when the United Nations Framework Convention on Climate Change (UNFCCC) treaty was signed, with nearly all countries

It is clear that there is no global consensus on how to convert from a petroleum-based economy to newer, greener, alternative technologies.

represented. While the UNFCCC treaty was a positive first step, it didn't include mechanisms to effectively monitor and enforce regulations or to penalize non-conformance. The Kyoto Protocol, an addition to the UNFCCC, was signed by all participating countries, and all but the United States ratified it prior to its becoming effective in 2005.

While the United Nations (UN) has made great strides in bringing countries around the world together on a number of topics that affect the common good, including climate change, it lacks the ability to closely monitor compliance and enforce regulations. To effect real change, countries and industries will most likely have to cooperate through a recognized worldwide body to ensure continuity and sustainability. Such an entity must also have a mechanism to penalize those countries that do not achieve emissions reduction targets.

Exhaust emissions and air quality will continue to be major challenges for the global community, especially as emerging countries (such as China and India) continue their rapid industrial and automotive industry growth. The challenge will be convincing both developed and emerging countries to adopt a cohesive and complementary plan that allows green vehicle technologies to be developed. This will be important to facilitating the mass migration to green vehicles in as short a time period as possible.

To effect real change, countries and industries will most likely have to cooperate through a recognized worldwide body to ensure continuity and sustainability.

Until then, regions, countries, and companies will be forced to spread their financial and human resources thin as they pursue all potential alternative technologies simultaneously. It will also force automaker competitors and suppliers to forge alliances in order to hedge all of their technology options. Indeed, this has already begun, with Daimler AG and BYD Auto announcing a joint venture to build electric vehicles for China, and Toyota Motor Corporation and Tesla Motors agreeing to jointly build electric vehicles in the United States. While industry cooperation is a good solution, the currently uncoordinated regulations of the world's largest automotive industries and markets will most likely delay the adoption of a single green solution in the future.

Challenges

As noted earlier, there are numerous challenges to developing a global hybrid and electric vehicle industry, including technology hurdles; consumer acceptance obstacles; financial barriers; infrastructure constraints; and the development of coordinated policies. These challenges often are intertwined, such as uncoordinated government policies that lead to numerous and sometimes conflicting avenues of technology development. This may lead to uneven levels of technology development among participating countries and industries, which may result in higher overall development costs, higher retail prices, and declining consumer acceptance. Some of the key challenges to be overcome with battery-based vehicles are:

- **Driving Range:** This is a critical issue for BEVs. Conversely, PHEVs typically have an electric-only driving range of 10-30 miles, plus an additional 300 or more miles using gasoline-engine power, while ER-EVs such as the Chevrolet Volt have a 30-50 mile all-electric driving range, plus an additional 250-350 miles using a gasoline or flex-fuel engine as a generator (according to General Motors, which manufactures the Volt). Current BEV offerings, such as BMW's MINI E or the Nissan Leaf, have stated ranges of 160 km (or 100 miles) on a full charge. However, this projected range is based on certain driving conditions, such as weather and cargo weight. While most consumers commute less than 160 km on a daily basis, on average, charging infrastructure for BEVs is still relatively non-existent in most places.

Lithium-ion (Li-ion) batteries are beginning to be utilized more often than are nickel-metal hydride (NiMH) batteries, given their lighter weight and an energy storage capacity that is nearly double that of a same-size NiMH battery. Moreover, engineering developments for Li-ion batteries indicate even greater potential for energy storage. In a test environment,

adding new graphite composites to the anodes of Li-ion batteries has reportedly resulted in storage capabilities four times greater than existing capabilities. If successful, this technology could substantially reduce concerns about driving range.

- **Infrastructure to Support Battery Charging:** Owners of BEVs or PHEVs will likely need to be able to recharge their vehicle's battery overnight at home. While this presents a viable solution for the majority of daily commuters, it poses possible challenges for vehicle owners with longer commutes. It is of even greater concern during extended driving periods, such as vacations or holidays, when vehicle owners are less likely to be in a location where they can recharge the battery. There is also a problem with commuters who live in apartments or other large community settings, where the infrastructure to recharge a BEV overnight may not exist, or where charging stations need to be shared. Considerable investment by governments and private industry will most likely be required to develop an electricity distribution and recharging infrastructure at parking meters and parking lots, office parks, and perhaps existing gasoline/petrol stations.
- **Power and Performance:** While some consumers are willing to accept reduced performance in exchange for cleaner vehicle emissions, the ecological benefits of HEVs and BEVs are not yet great enough to convince the majority of owners to forego their ICE-powered vehicles for green technology vehicles. Driving on mountainous or hilly roads with frequent steep inclines puts a tremendous strain on both HEVs and BEVs, resulting in reduced power and a substantially reduced driving range. Battery electric vehicles also tend not to perform as well in colder climates, where more energy is generally needed to power all vehicle functions. All of these factors must be considered by consumers before they purchase a vehicle that relies on battery power.
- **Fuel Economy (\$/km):** Prospective HEV and PHEV buyers must consider the higher vehicle purchase price and decrease in performance, compared with the expected increase in fuel economy. In addition to the substantially higher price of BEVs, the cost of electricity needs to be considered. If the growth in electricity generation—and the creation of an electric distribution infrastructure—lags that of the adoption of PHEVs, ER-EVs, and BEVs, all else being equal, the cost to recharge these types of vehicles could rise substantially.
- **Emissions:** For environmental purists, even BEVs can produce greenhouse emissions, though higher up the energy-creation chain at electricity-generating powerplants. The way in which electricity is generated may become more critical to the debate regarding the long-term viability of battery-based vehicles to decrease emissions. Substituting fossil-fuel-based vehicles with PHEVs, ER-EVs, and BEVs that utilize electricity generated by coal or oil would possibly negate one of the primary reasons for switching to these alternative solutions.
- **Battery Life and Replacement Costs:** Although there is insufficient data regarding the typical BEV battery life span, BEV battery packs are believed to be the costliest component to replace. A Li-ion battery, for example, is expected to have a useful life of up to 200,000 km (124,000 miles), and the cost to replace the battery pack is expected to range from US \$10,000 to US \$15,000. Unless the expected battery life can be increased or the replacement price decreased, as BEVs enter the pre-owned market and more data is gathered, there will likely be significant downward pressure on vehicle residual prices and, hence, an increase in the total cost of vehicle ownership.
- **Vehicle Cost:** This is probably the greatest challenge for HEVs and BEVs and is typically directly related to the battery, which is either NiMH or Li-ion. Many governments are providing subsidies toward the purchase of an HEV or BEV, but these incentives are not conducive to creating sustainability over the long term. At some point, the widespread production and sale of HEVs and BEVs need to be profitable.

The ecological benefits of HEVs and BEVs are not yet great enough to convince the majority of owners to forego their ICE-powered vehicles for green technology vehicles.

- **Time to Recharge the Battery:** Typical BEVs utilize a standard household plug and require up to 8 hours for a full recharge. Obviously, this recharge period must be shortened if these vehicles are to be used for more than just commuting. While some companies claim to have achieved much shorter recharging periods, these periods are still substantially longer than the few minutes needed to refuel a traditional ICE-powered vehicle.

Much more work must be done regarding battery-based vehicles to become economically sustainable and win consumer acceptance. The key focus should be on creating and improving infrastructure and extending the driving range of BEVs. Until then, there will likely be heavy reliance on more mature technologies to reduce costs to the industry and prices to consumers.

Battery-Based Technologies

United States



“So we have a choice to make. We can remain one of the world’s leading importers of foreign oil, or we can make the investments that would allow us to become the world’s leading exporter of renewable energy. We can let climate change continue to go unchecked, or we can help stop it. We can let the jobs of tomorrow be created abroad, or we can create those jobs right here in America and lay the foundation for lasting prosperity.”

—US President Barack Obama, March 19, 2009

Overview

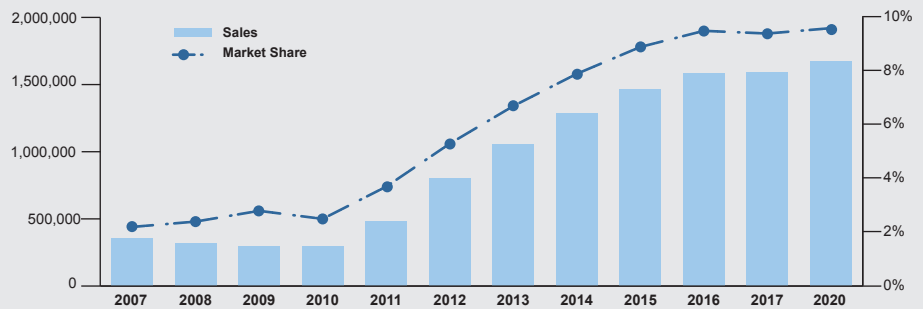
- Since at least the beginning of the 20th century—when it became the world’s pre-eminent industrial power—the United States has been the largest consumer of oil in the world; even today, it accounts for approximately 22% of the worldwide consumption of oil each day.
- For much of the past 100 years—and up until 2009, when it was surpassed by China—the United States also achieved the world’s highest sales of vehicles each year.
- Today, there are some 250 million passenger vehicles on US roads, far more than in any other country. Most of these vehicles are powered by internal combustion engines (ICEs), which burn oil-based fuels and are the cause of a substantial percentage of greenhouse-gas emissions.
- Given that the vast majority of the oil consumed in the United States is imported, it should not be unexpected that the US government has become interested, especially recently, in promoting an energy alternative to oil, which has a grip on the nation’s economy and automotive lifestyle.
- Yet, despite the economic, environmental, and geopolitical anxieties caused by the dependence on oil, J.D. Power and Associates expects that, based on the relatively stable supply of global oil forecasted to be available through 2020, the US automotive industry and market will remain heavily dependent on oil during the next decade.
- As a result, while the migration to alternative-energy vehicles (particularly hybrid electric vehicles, or HEVs) will result in a growth spurt in the United States during the next 10 years, these vehicles will remain a small fraction of total annual sales.



US Passenger-Vehicle Sales Outlook: HEVs

- In 2009, combined sales of hybrid electric vehicles (HEVs), including plug-in hybrid electric vehicles (PHEVs), reached 291,600 units, or about 2.8% of all passenger vehicles sold that year. The United States also accounted for nearly 40% of all HEVs sold around the world in 2009.
- Sales of HEVs in the United States in 2010 are expected to reach 291,000 units, which also translates into just 2.5% of all passenger-vehicle sales in the country for the year and 36% of all HEVs sold worldwide.
- The reason for the decline in HEV sales in the United States in 2010 as a percentage of the global total is that sales are expected to grow faster in other major regions around the world, especially in Japan and Europe.

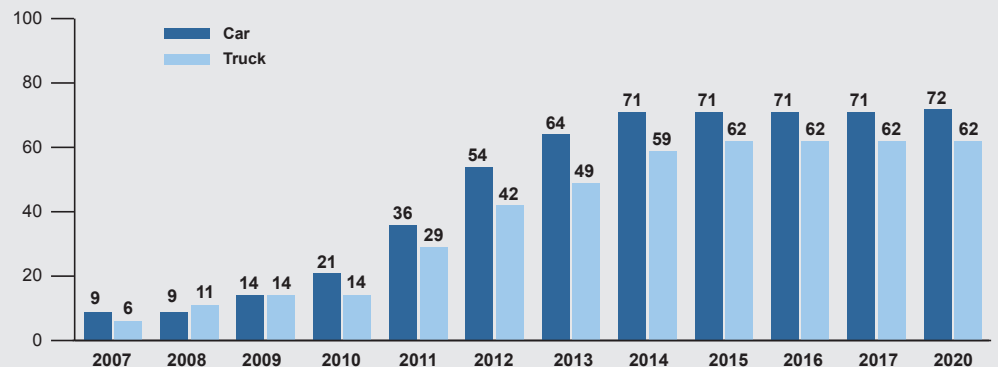
US: Sales of HEVs and PHEVs—2007-2020



Source: J.D. Power Global Forecasting

- Going forward, sales of HEVs are expected to grow at an accelerated rate as more models become available, and as more consumers become comfortable with the new technology and infrastructure develops to more widely support PHEVs.
- Still, US sales of HEVs are expected to reach 1.67 million units by 2020, or less than 10% of all passenger vehicles sold. Overall, the United States will account for more than 43% of hybrid sales in 2020.
- The number of HEV models in the United States is expected to grow from just 28 in 2009 to 35 in 2010, and to 134 by 2020.

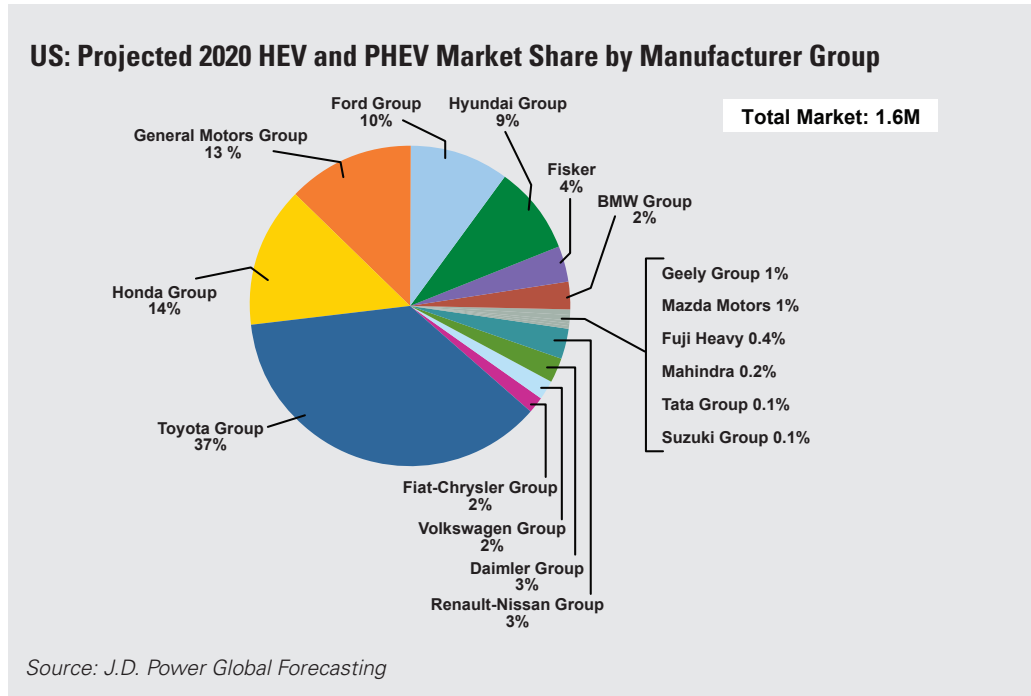
US: Number of Global HEV and PHEV Models per Year—2007-2020



Source: J.D. Power Global Forecasting



- While more than 20 automakers will be selling HEVs in 2020, the top five automotive groups will account for more than 80% of all sales. These groups include the Toyota Group, Honda Group, General Motors Group, Ford Group, and Hyundai Group.

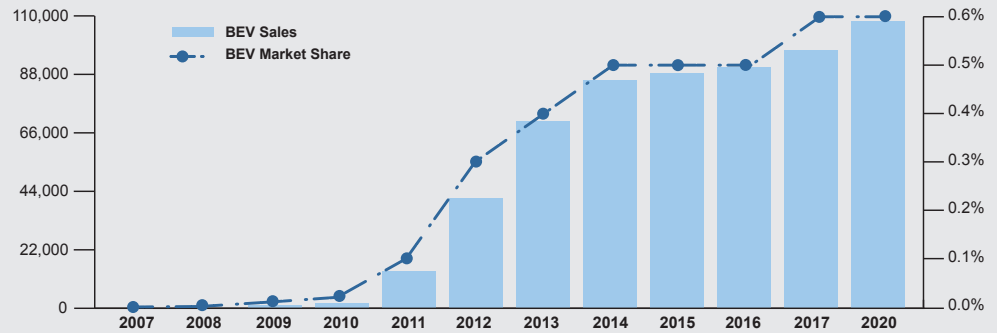


US Passenger-Vehicle Sales Outlook: BEVs

- In 2010, battery electric vehicles (BEVs) in the United States include the US \$100,000 Tesla Roadster and the limited-lease-only BMW MINI E.
- The Nissan Leaf, to be launched in late 2010 or early 2011, will likely become the best-selling BEV beginning in 2011.
- Also in 2011, the Mitsubishi Group is expected to launch the iMiEV in the United States (although it has been available in Japan since 2009), and the Ford Group is expected to launch an electric version of the new Focus beginning in 2011.
- The Volkswagen Group expects to launch the E-Up! in the United States in 2013, and Audi plans to launch either a compact BEV and/or a BEV sports car in 2014.
- Given the challenges with technology, cost, supporting infrastructure, and consumer acceptance that BEV manufacturers face, sales are expected to remain minimal during the next decade.
- BEV sales are expected to grow from just a few thousand units in 2010 to 107,000 units by 2020, which represents less than 1% of all passenger-vehicle sales in the US market.



US: Sales of BEVs—2007-2020



Source: J.D. Power Global Forecasting

Profile of HEV Consumers in the United States

Since the number of BEV buyers in the United States is limited, there is insufficient data to develop an accurate demographic profile; however, J.D. Power has significant data on HEV buyers and the factors that shape their purchase behavior.

Demographics

- According to several J.D. Power automotive studies, HEV buyers tend to be slightly older and are more highly educated than are a large majority of buyers of gasoline-powered vehicles.
- In particular, more than 40% of HEV buyers have a postgraduate degree, which is significantly higher than in the other two buyer segments.

US New-Vehicle Buyer Demographics (2010)

	Gas Buyers	Diesel Buyers	Hybrid Buyers
Gender			
Male	58%	79%	59%
Female	42%	21%	41%
Age			
Median Age	54	52	57
Education			
4-Year College Degree	26%	26%	24%
Some Graduate Courses	6%	7%	8%
Advanced Degree	24%	27%	42%
Marital Status			
Married	74%	80%	77%
Single (Never Married)	12%	10%	10%
Household Income			
Median Income (USD)	91,089	122,248	110,683

Source: J.D. Power and Associates 2010 Initial Quality StudySM (IQS)

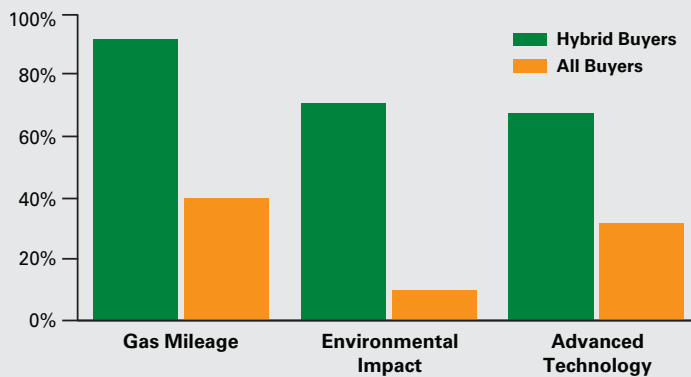


- The median household income level for HEV buyers is US \$110,000, which is 22% higher than the median household income for buyers of gasoline-powered vehicles (US \$91,000), but lower than the median household income for buyers of diesel-powered vehicles (US \$122,000).
- In terms of gender, HEV buyers tend to track very closely with the majority of passenger-vehicle buyers (i.e., buyers of gasoline-powered vehicles), with 60% male and 40% female. In contrast, the percentages of male buyers of diesel and flex-fuel-powered vehicles are much higher, with males accounting for 75%-80% of these vehicle purchases.

Purchase Behavior

- In comparing the three most important factors when considering a new passenger vehicle, there are significant differences between HEV buyers and all vehicle buyers:
 - More than 90% of HEV buyers cite gas mileage as one of the most important factors for their purchase, compared with just 40% of all buyers.
 - More than 70% of HEV buyers cite environmental impact as a key purchase factor, compared with just 10% of all buyers.
 - Nearly 70% of HEV buyers cite the importance of having advanced technology in their vehicle, compared with just 32% of all buyers who have the same priority.

Top Three Most Important Factors for Hybrid Buyers vs. All Buyers

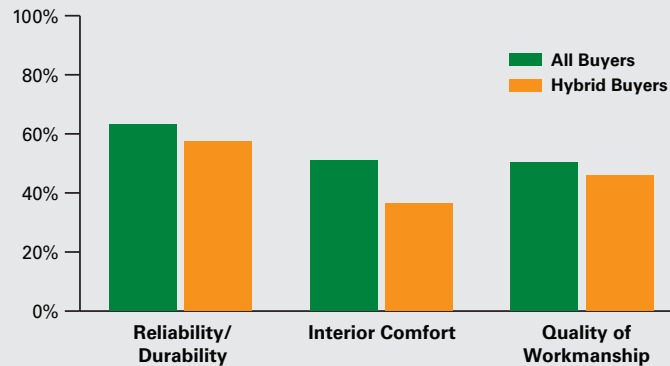


Source: J.D. Power and Associates 2010 Initial Quality StudySM (IQS)

- In comparing the three most important purchase factors among all buyers with HEV buyers, the differences are almost as equally pronounced as for consideration:
 - More than 63% of all buyers cite reliability/durability as one of the most important factors for their purchase, compared with 57% of HEV buyers.
 - Nearly 50% of all buyers cite interior comfort as a key purchase factor, compared with 36% of HEV buyers.
 - While 50% of all buyers cite the importance of quality of workmanship as one of the most important factors in their purchase, 46% of HEV buyers say the same.



Top Three Most Important Factors for All Buyers vs. Hybrid Buyers

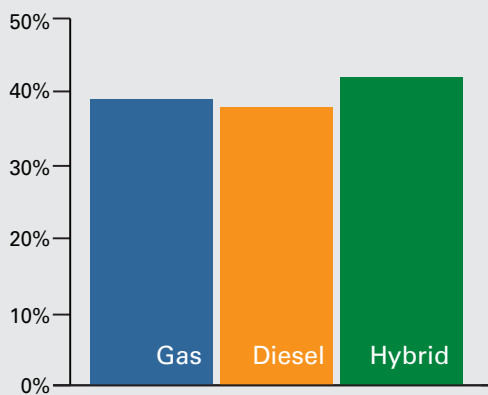


Source: J.D. Power and Associates 2010 Initial Quality StudySM (IQS)

- Clearly, the factors that help drive the purchase decision for most new-vehicle buyers are not nearly as important to HEV buyers. Based on their demographics and their purchase priorities, HEV buyers comprise a unique niche.
- To further exacerbate the challenge of selling green passenger vehicles to the mass market, while many HEV buyers say that fuel economy and environmental impact are two of their top priorities, research shows that they are only slightly more willing to buy an eco-friendly vehicle than are traditional gasoline or diesel buyers.

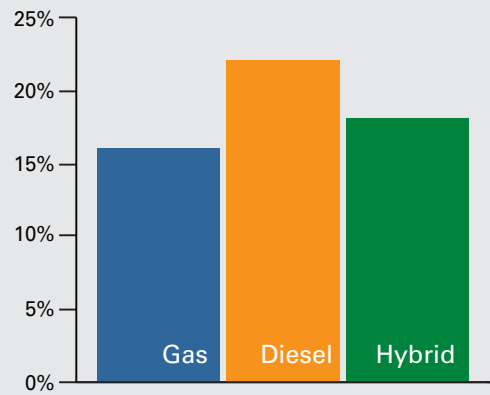
"My first consideration is fuel economy"

(Completely Agree)



"I am willing to pay more for an eco-friendly car"

(Completely Agree)



Source: J.D. Power and Associates 2010 Initial Quality StudySM (IQS)

J.D. Power research also shows that among US new-vehicle intenders who are interested in buying an HEV, their stated interest to buy declines by 50% once they are advised of the price premium for a green vehicle.

- J.D. Power research also shows that among US new-vehicle intenders who are interested in buying an HEV, their stated interest to buy declines by 50% once they are advised of the price premium for a green vehicle.
- Going forward, government subsidies—either to the manufacturer or the buyer—will continue to serve as the main driving force of HEV and BEV sales. However, without any permanent increase in the price of gasoline (either by market forces or taxation), or a significant decline in the price of HEVs and BEVs, an increase in consumer acceptance and consideration of buying these vehicles will likely be limited.



Government Policy

- In April 2010, the US government announced new Corporate Average Fuel Economy (CAFE) standards for cars and light trucks sold in the United States of 35.5 mpg (6.63L/100km) for the 2016 model year—an increase of 8.2 mpg (1.99L/100km) between 2011 and 2016.
- The US government estimates that by 2020 the new standards will lead to a reduction of greenhouse-gas (GHG) emissions of 209 million metric tons (the equivalent of taking 31 million of today's vehicles off the roads in the United States); a reduction of US oil consumption by 1.2 million barrels per day; and savings at the pump to consumers of between \$34 and \$58 billion (provided gasoline prices continue to range from \$2.75 to \$4.00 per gallon).
- Each model's fuel economy target is dependent on the "footprint" of the model, which represents the wheelbase multiplied by the average of the front track and rear track. Vehicles with a small track will have a higher mpg standard to meet than a larger model, such as an SUV or pickup truck.
- The expected cash savings realized by consumers at the pump will likely be offset by higher retail prices paid for their new vehicle. To meet the new CAFE rules, it is expected that automakers will incur tens of billions of dollars in vehicle development costs and in changing over production at their manufacturing plants to produce smaller vehicles. This cost will likely be passed on to consumers at the time of their new-vehicle purchase.
- As a result of the higher CAFE targets, automakers are increasingly interested in introducing HEV and BEV technologies, if it can be done on a cost-effective basis.
- One way to promote the sale of alternative-fuel vehicles is to provide subsidies to manufacturers and tax incentives to consumers. Current federal credits for various types of alternative-energy passenger vehicles include:

Vehicle Type	Credits	Vehicle Examples
Hybrid Electric Vehicles (HEVs)	Credits range from \$250 to \$3,400*	Toyota Prius, Honda Insight
Battery Electric Vehicles (BEVs)	\$7,500	Nissan Leaf, Tesla Roadster
Plug-In Hybrid Electric Vehicles (PHEVs) and Extended-Range Electric Vehicles (ER-EVs)	\$7,500	Toyota Prius PHEV, Chevrolet Volt ER-EV
Clean-Diesel Vehicles	Range from \$900 to \$2,200	BMW 335d, VW Jetta TDI

* Expired in March 2010

Source: J.D. Power and Associates Research

- One immediate implication of the new fuel economy standards is that stop-start technology, which debuted on hybrid electric vehicles as a fuel savings and was touted as an exhaust-emission-reduction measure, will likely become a standard feature on many ICE-powered vehicles in the near future.



- While the US government has increased CAFE targets and is providing financial incentives to promote cleaner and more fuel-efficient vehicles, it has largely ignored perhaps the most effective (yet admittedly politically charged) tool at its disposal for promoting cleaner and more efficient vehicles: imposing higher taxes on petroleum-based fuels.
- While other developed economies have taxed gasoline and diesel heavily for years—with the effect of creating fleets of vehicles with high fuel economy and low emissions—there has not been an increase in the gasoline tax in the United States since 1993. Increasing taxes on petroleum-based fuels is a politically sensitive topic, and politicians are generally reluctant to consider it for fear of damaging their standing with voters.

Conclusion

As with all global markets, one major challenge to the ability of the United States to grow a market suitable for mass consumption of PHEVs and BEVs is developing the appropriate infrastructure to support these vehicles. This will require substantial planning and investment to be accomplished effectively.

Compared with China, Europe, and Japan—where many large populations are concentrated in relatively small urban areas—the potential for HEVs and BEVs in the United States faces at least two significant hurdles:

- Long daily commutes that have resulted from city-to-suburban migration throughout much of the United States are not conducive to maximizing the benefits of alternative-fuel vehicles, particularly BEVs. “Range anxiety” endemic to BEVs leaves consumers uneasy about whether they can achieve their daily commute on a single charge.
- US consumers have grown accustomed to large and powerful vehicles, and automakers will be challenged to continue to meet their size, comfort, and power expectations, while simultaneously increasing range and fuel economy.

Economic sustainability presents another challenge for HEVs and BEVs. Without government-backed incentives and subsidies for both consumers and manufacturers, there is a question as to whether automakers can profitably build and sell HEVs and BEVs in an environment expected to remain defined by affordable petroleum-based fuels.

The US government has shown no indication that it intends to tax or penalize buyers of low-fuel-economy passenger vehicles. Until it becomes financially disagreeable for consumers who buy these vehicles, the chances of rapidly developing a national passenger-vehicle fleet characterized by HEVs and BEVs seem remote.

Interview

John Hanson

*National Manager, Environmental, Safety and Quality Communications
Toyota Motor Sales U.S.A., Inc.*



With the success of its Prius hybrid, Toyota Motor Corporation became the first automaker to achieve volume sales of an alternative-fuel vehicle. While Toyota is developing other alternative-fuel vehicles, it sees conventional hybrids as occupying the spotlight for some time to come. John Hanson, National Manager, Environmental, Safety and Quality Communications for Toyota Motor Sales U.S.A., Inc., spoke to J.D. Power and Associates about the role of different technologies in the market during the next 5 years and the barriers to more widespread adoption of some of those technologies.

J.D. Power: Among hybrid, plug-in hybrid, extended-range hybrid, and battery electric-powered cars, which one do you think will have the greatest sales volume over the next 5 years? Why?

Hanson: *Conventional hybrids, such as Prius. The plug-in hybrids are going to be a niche because of the convenience factor and the extra-cost factor. You will see small volume in the plug-in hybrids. Same with straight battery electric, such as the Nissan Leaf. You are dealing with a really cost-sensitive consumer out there. The adoption will be slow.*

J.D. Power: How large of a role do you think diesel, natural gas, and hydrogen will have as a fuel source over the next 5 years?

Hanson: *I don't believe diesel will have a huge impact. American consumers don't see the need for it. Natural gas and hydrogen have infrastructure issues. Right now, if you want compressed natural gas, you have to go to an industrial yard behind a gate. Currently, there aren't even standards in place to price hydrogen. There is going to have to be a real partnership approach between government and industry to build infrastructure. There will be, because major manufacturers are coming to market with very good hydrogen fuel-cell products. GM, Toyota, Honda, Hyundai, [and] Daimler will in the next 5 years have very good fuel-cell products.*

J.D. Power: In your opinion, what is the greatest impediment to a more widespread adoption of battery electric vehicles over the next 5 years?

Hanson: *Cost, convenience, and infrastructure. There are many people who will wave an extension cord in front of you and say this is the infrastructure for plug-in electrics. But, there really is range anxiety. The bigger the battery, the more wide the range values can be, depending on how you drive the vehicle.*

J.D. Power: How much longer do you think the internal combustion [engine] will be used for passenger vehicles? Why?

Hanson: *For quite a long time. The biggest reason is that ICEs continue to improve in efficiency through a wide variety of advancements. Very soon, internal combustion engines will be approaching the efficiencies of current hybrids. Also, we will start seeing the use of low-carb fuels made out of things like algae that can be burned in a combustion engine. In general, you are going to see long-term use of ICEs in tandem with hybrid technology.*

J.D. Power: When do you foresee the availability of affordable (i.e., mainstream) hydrogen fuel-cell vehicles? Why?

Hanson: *There is no way to predict at this point when hydrogen fuel cell will have significant market share of 10% or more. The consumer is going to decide. Look at how long it has taken us to have even a full percentage point of hybrid vehicles in any market. Hydrogen fuel cell will be available, selling in very small numbers. It will improve with the amount of infrastructure.*

J.D. Power: Do hydrogen fuel cells have a chance as an “end-state” solution?

Hanson: *I don't know. It is a wonderful technology. We have to come up with low carbon ways of producing hydrogen. Then there is the large investment in the refueling stations. It's hard to gauge if it will become a dominant force.*

Interview

Robert Bienenfeld

*Senior Manager, Environment and Energy Strategy
American Honda Motor Co., Inc.*



American Honda Motor Co., Inc. has been ahead of the market with respect to alternative-fuel vehicles. The Insight, launched in 1999, was the first gasoline electric vehicle on the market in the United States. However, it was a small two-seater, and sales were limited. Honda also began producing a compressed natural gas-powered Civic in 1998. A few are on the roads in California.

The hybrid Civic sedan, introduced in Japan in 2001, failed to catch on, as did the second-generation Insight. Honda was also a pioneer when it launched the FCX Clarity fuel-cell electric vehicle in mid-2008. However, a high price and the lack of a refueling infrastructure means only a few hundred are on the road today. With the public's growing desire for hybrids, however, Honda is seeing more demand for the Civic hybrid. Consequently, in June 2010, Honda launched the CRZ, a sporty hybrid coupe.

Robert Bienenfeld, Senior Manager, Environment and Energy Strategy at American Honda Motor Co. talked to J.D. Power about the government's role in the market for alternative-fuel vehicles, and what role the different technologies will play in the future market.

J.D. Power: Apart from meeting CAFE mandates, what role should the automakers take in reducing harmful tailpipe emissions and ending our dependence on petroleum?

Bienenfeld: *In the last 40 years, OEMs have reduced harmful, smog-forming emissions by as much as a thousandfold, from 10 grams of hydrocarbons/mile to 0.01 grams/mile. The reliability and durability of these emissions reductions are substantial, and amazing progress has been made. Many believe that the next round of emissions regulations—LEV III and Tier III—will effectively end the role of automobiles as a major source of smog-forming pollutants. Unfortunately, our transportation system is more than 95% dependent on petroleum. Even if fuel economy and greenhouse gas regulations dramatically reduce our consumption of petroleum in the next 20 years, we could end up consuming much less petroleum, but still be 95% dependent on petroleum.*

J.D. Power: How much longer do you think the internal combustion engine will be used for passenger vehicles? Why?

Bienenfeld: *Internal combustion engines and the petroleum products that fuel them are tough incumbents for any alternative fuel to beat out. Existing ICE volumes are high, so costs are relatively low. And while inexpensive conventional oil seems to be peaking, there is no lack of unconventional sources for petroleum-type fuels. So the answer to this question depends entirely on social attitudes and political will. Engineers are working furiously to make ICEs ever cleaner, using less and less fuel. This means that the operating costs for ICEs will continually reduce, raising the bar for alternatives.*

J.D. Power: How large of a role do you think diesel, natural gas, and hydrogen will have as a fuel source over the next 5 years?

Bienenfeld: *The German companies see a huge potential business in diesel. I have heard BMW, Daimler, and VW say they think they can sell as much as 40% of their volume in diesel. [Hydrogen] fuel-cell electric vehicles are still in their infancy, and while I think their development and market rollout is significant, I think their volume will remain small. Compressed natural gas is doing very well in the medium- and heavy-duty ends of the market. The fuel savings is significant and can pay for the upfitting. The CO₂ reductions are great, and the infrastructure, while significantly less than gasoline, is robust and substantial in many areas. Compressed natural gas volume for Honda is small, and we are seriously studying how to grow this business.*

J.D. Power: When do you foresee the availability of affordable (i.e., mainstream) hydrogen fuel-cell vehicles? Can hydrogen fuel-cell vehicles achieve a market share of 10% or more? Do they have any chance of being an end-state solution?

Bienenfeld: *Fuel-cell electric vehicles are very promising because their well-to-wheel CO₂ profile is very good, and compare very favorably against battery electric vehicles and plug-in hybrid electric vehicles, since the US energy grid is so dirty. Even when the US grid is cleaned up, fuel-cell electric vehicles look quite good. Fuel-cell electric vehicles have ranges similar to gasoline vehicles—the [Honda] Clarity has a range of roughly 240 miles.*

According to the California Fuel Cell Partnership, we are moving into three phases of fuel-cell electric vehicle volumes—the current phase is in the hundreds, the next phase, 2012–2014, is in the thousands, and the post-2015 phase is in the tens of thousands. There remain cost, technical, and infrastructure challenges to overcome; however, fuel-cell electric vehicles remain promising.

Interview

Shai Agassi

Founder and CEO, Better Place



The lack of a recharging infrastructure—and the question of who should pay to build one—is a major barrier to the widespread adoption of electric vehicles. Better Place thinks it has the solution.

The stated mission of Better Place, based in Palo Alto, California, in the heart of Silicon Valley, is “to accelerate the global transition to sustainable transportation.” Better Place aims to install a network of charge spots and battery switch stations that it has developed.

The company conducted a 90-day test of its electric-battery switching stations with a taxi fleet in Tokyo beginning in April 2010. A full-scale test of the business model—including charge spots, battery switching stations, and network management software—is scheduled to begin in Israel at the end of 2010. Better Place intends to commercially launch its solution in Israel and Denmark in late 2011.

Better Place Founder and CEO Shai Agassi, a former software firm executive, discusses why he thinks battery-powered electric vehicles will be the preferred green technology, and the role of government in promoting and financing the market for electric vehicles.

J.D. Power: There is a variety of alternative-fuel options out there today: diesel, hydrogen, natural gas. Why are you so convinced electric is the future?

Agassi: *The beauty of electric cars is that the underlying infrastructure and technology exists now. The grid is in place and with the right support and infrastructure we can move quickly to scale this across countries. When it comes to other alternatives like hydrogen, natural gas, etc., this is not the case. None of these other alternative technologies are ready today for mass market, and the infrastructure does not exist to support these vehicles.*

J.D. Power: What is the largest barrier you face in the widespread adoption of electric cars in the next 5 years?

Agassi: *Breaking the status quo is truthfully the biggest challenge. The EV technology is there, the cars will be fantastic, but it will come down to creating a consumer proposition that breaks the mold, making electric cars more convenient and affordable than today's gas cars. We cannot ask consumers to sacrifice on price, convenience, or performance to be green. Getting people to accept this is something we can do, and it doesn't require significant behavioral changes.*

J.D. Power: What is the role of government in this new era of alternative transportation?

Agassi: *Government is critical to creating the market conditions for mass-market adoption of EVs. For EVs to scale and become mass market, it will be critical that they help support the deployment of charging infrastructure.*

J.D. Power: Who is responsible for financing the infrastructure, something that can be very expensive?

Agassi: *Better Place is responsible for the buildout of our network of battery switch stations and charge spots. Much like the rollout of mobile telephony networks, we believe that the CAPEX required to finance our network deployment will come from a variety of sources, including equity, government loans and grants, project financing, and vendor financing.*



Interview

Andrew J. Littlefair

President and CEO

Clean Energy Fuels Corp.

Clean Energy Fuels Corp., founded by natural gas booster T. Boone Pickens, promotes natural gas as an alternative clean-transportation fuel. It owns and operates LNG production plants, and designs, builds, and operates natural gas refueling stations.

The current customer base of Clean Energy is comprised of fleet operators, including Los Angeles International Airport and Super Shuttle International, and municipal fleets in the United States and Canada.

Andrew J. Littlefair is President and Chief Executive Officer of Clean Energy Fuels Corp., based in Seal Beach, California. He also is Chairman of NGV American, a national organization based in Washington, D.C., which is dedicated to developing a market for natural gas-powered vehicles.

Littlefair spoke to J.D. Power and Associates about the future of various alternative fuels, the barriers to more widespread use of natural gas and other options, and the role of the government in promoting alternative fuels.

J.D. Power: Among hybrid, plug-in hybrid, and extended-range hybrid, which one do you think will have the greatest growth over the next 5 years?

Littlefair: *I am for all these alternatives. It is not easy to introduce an alternative-fuel vehicle into the marketplace. For the near to midterm, the [gas] hybrid will be the most prolific. Plug-in hybrids are going to be harder to introduce than most people think. I'm not sure the infrastructure is as easy as some people think.*

J.D. Power: How large of a role do you think diesel, natural gas, and hydrogen will have as a fuel source over the next 5 years?

Littlefair: *Clean diesel is not going to sell. It's a German-inspired deal. I don't think diesel is that plentiful. A lack of refining capacity means diesel will be expensive. The US has a huge amount of natural gas now. We have three times as much natural gas as Saudi Arabia has oil. Does that mean every vehicle can be a natural gas vehicle? No. It is appropriate for goods movement, fleet vehicles, and the like. Europe has 62 natural gas-powered car models; we have one. But, I think natural gas has a pretty bright future.*

J.D. Power: How about hydrogen?

Littlefair: *Hydrogen, maybe for the longer term. I own and operate a hydrogen-fueling station, [but] hydrogen is still \$16-\$18 a gallon. We give it away. The economics there are difficult. An efficient introduction of hydrogen needs nuclear. That is a long way out.*

J.D. Power: How much longer do you think the internal combustion engine will be used for passenger vehicles?

Littlefair: *I think the combustion engine will hold a very large part of the market for the next 35 years. You will put different fuels in it and make a hybrid, natural gas, blend.*

J.D. Power: Apart from meeting CAFE mandates, what role should the automakers take in reducing harmful tailpipe emissions?

Littlefair: *You have to give them some credit. They have made the internal combustion engine a lot cleaner. They have to sell vehicles people want to buy. Properly [incentivized], with costs appropriately recognized, they have a responsibility to clean up the tailpipe.*

J.D. Power: What responsibility do automakers have in reducing our collective dependency on oil?

Littlefair: *The automakers understand that we do face a dilemma. They understand that the situation is fragile, given geopolitical concerns. That's where natural gas can help with some of this. They are mindful of the fact Americans are uncomfortable with the imported oil situation. They do have a responsibility to their shareholders to not be in a position where they can't sell a vehicle when the price of fuel goes up.*

J.D. Power: In the absence of a huge hike in the price of gas, can government subsidies create a viable market for alternative-fuel vehicles? What else should the government do to promote alternative-fuel vehicles?

Littlefair: *I think so. Does it have to be in place forever? No. Would some incentives help? Sure. You have to give some incentives to change behavior. The federal government doesn't buy a lot of alternative-fuel vehicles. They could lead by example. They could 'jawbone' it, they could show some leadership.*



Interview

Ed Begley Jr.

Actor and Environmentalist

Actor and environmentalist Ed Begley Jr. promotes green technology through his television show, “Living with Ed,” which begins its fourth season on the Discovery Channel. The show follows Begley and his wife and daughter as they try to live green, from using electricity from solar panels to recycling water.

Begley was an early adopter of electric vehicles—he bought a Taylor-Dunn EV in 1970, partly to help fight the notorious smog problem in Los Angeles and partly because it was cheap. Today, he often appears at Hollywood events on his bicycle.

Begley speaks on a variety of environmental topics and is on the board of directors of many environmental organizations. Begley provided J.D. Power and Associates his thoughts on the role of automakers, the government, and consumers in expanding the use of green vehicles.

J.D. Power: Apart from meeting CAFE mandates, what role should automakers take in reducing harmful tailpipe emissions?

Begley: *I met with William Clay Ford in April 2010 and he’s being quite proactive on sustainability. So, I think Ford is well-positioned because of the many green choices they’ve made in recent years. The green living rooftop on their plant in Dearborn is just one example. Further examples include the sustainable materials that they are starting to make their cars out of, and most importantly, the wide selection of alternative-fueled vehicles they will start offering this fall.*

J.D. Power: What can the government do differently or additionally to promote the use of alternative-fuel vehicles?

Begley: *If you are going to ask folks to get an electric car, a natural gas vehicle, or a car that runs on biofuels, you must have an infrastructure of electric chargers, NGV fueling, and biofuel ready to pump to meet that need.*

J.D. Power: Should the cost to improve the electric infrastructure to meet the needs of the growing demand for battery electric vehicles be borne by the entire consumer base or integrated into the cost of the vehicle?

Begley: *This is probably heresy, but I think we should get that money from gasoline taxes. We’ll all benefit with cleaner air and less spills in the Gulf.*

J.D. Power: What is the greatest impediment to a more widespread adoption of battery electric vehicles over the next 5 years?

Begley: *The range. Gasoline has been popular because you can store 60 miles worth of distance in an 8-pound container known as a gallon. But the interesting thing is that most folks could live within the range of today’s battery electric pack. Unless you’re a traveling salesman, or live WAY out in the ‘burbs, today’s 100-mile range is sufficient for 90% of the population.*

Battery-Based Technologies

Europe



“Over the last 10 years, we have concentrated on measures to improve mobility whilst decoupling transport emissions from economic growth. Today, we can see that the extensive investment in transport infrastructure has enabled us to travel further to meet our daily needs, but has not led to a decrease in the amount of time that we are exposed to noise, congestion and air pollution. ... In the future, we will need to focus not only on the mode of transport, but also the reasons why people choose to travel, because ultimately mobility is inextricably linked to our quality of life.”

—Professor Jacqueline McGlade,
Executive Director of the European Environment Agency (EEA)

Overview

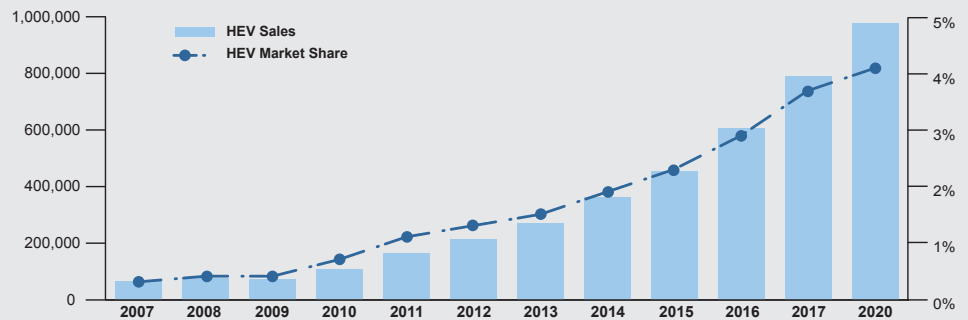
- European countries have some of the strictest exhaust-emission regulations in the world, and as a result, consumers in those countries already buy some of the smallest, most fuel-efficient and environmentally friendly passenger vehicles.
- Higher taxes on gasoline and diesel fuel—as well as high carbon taxes in some countries—have motivated many European consumers to buy more fuel-efficient vehicles. Regardless of their motivation, the sustainability of transportation is a serious issue among many European consumers.
- Nearly twice as many vehicle buyers in Germany as in the United States cite environmental impact as an important factor when purchasing a new vehicle.
- Diesel passenger vehicles—which have high fuel economy and low CO₂ emissions—have a significantly higher market penetration in Europe (more than 50%) than in any other major industrialized market.
- With the advent of clean-diesel fuel and exhaust-scrubbing technology, Europe is already well positioned to reduce its output of greenhouse-gas emissions.
- During the next decade, as European policy deals less with regulations on greenhouse gases and more on particulate-matter emissions, J.D. Power expects that the percentage of diesel engines will decline in Europe, and diesels slowly will be replaced by hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs).
- HEV sales in Europe vary considerably from one country to the next, which may be directly related to available financial incentives. One exception may be premium vehicle segment hybrids, for which there is less sensitivity to acquisition costs.
- The difference in sales of green vehicles among European countries suggests that the buying proposition for current hybrids is not sufficient to compete on a level playing field with alternatives such as diesel-powered or small gasoline-powered vehicles. Hence, there is a higher expectation in Europe for hybrid growth than an actual migration to these green vehicles.
- Currently, the UK is the biggest single European market for hybrids, followed by France and Germany.



European Passenger-Vehicle Sales Outlook: HEVs

- While diesel penetration is high in Europe, sales of HEVs, including plug-in electric vehicles (PHEVs), remain relatively low, compared with other regions in the world.
- J.D. Power data indicates that 73,500 HEV passenger vehicles were sold in Europe in 2009, representing just 0.4% of total passenger-vehicles sales (virtually identical to Europe’s HEV sales in 2008); 2010 HEV sales are expected to jump significantly to 107,000 units, but this figure is still lower than in Japan and the United States.
- The hybrid share of the European market remains low for at least two reasons. First, Europe’s well-established diesel sector offers fuel economy similar to that of gasoline-hybrid vehicles, but at a lower purchase price for comparable vehicles. Second, choices available to consumers who would prefer a hybrid remain limited—just eight HEV models are currently available, and only three are offered in the non-luxury segment.

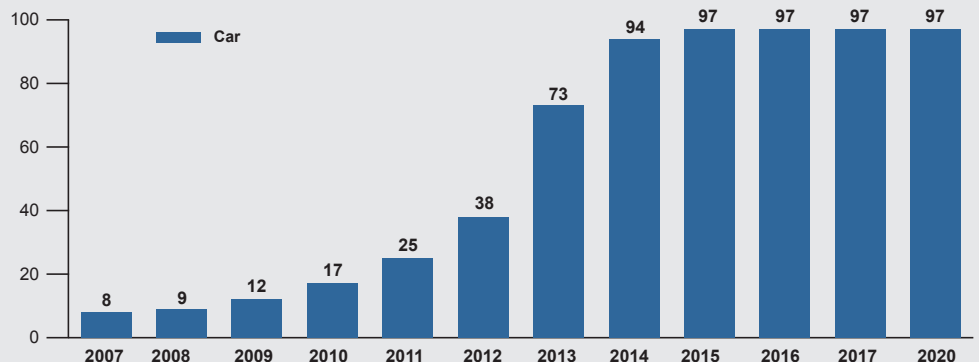
Europe: Sales of HEVs and PHEVs—2007-2020



Source: J.D. Power Global Forecasting

- HEV sales are expected to spike in the next decade—reaching 977,000 units in 2020—as European regulators look to curb vehicle emissions.
- Sales of HEV/PHEVs are expected to gain traction in Europe in the future as more manufacturers enter the market. The number of HEV models in Europe is expected to grow from just 12 in 2009, to 17 in 2010, and to 97 by 2020.

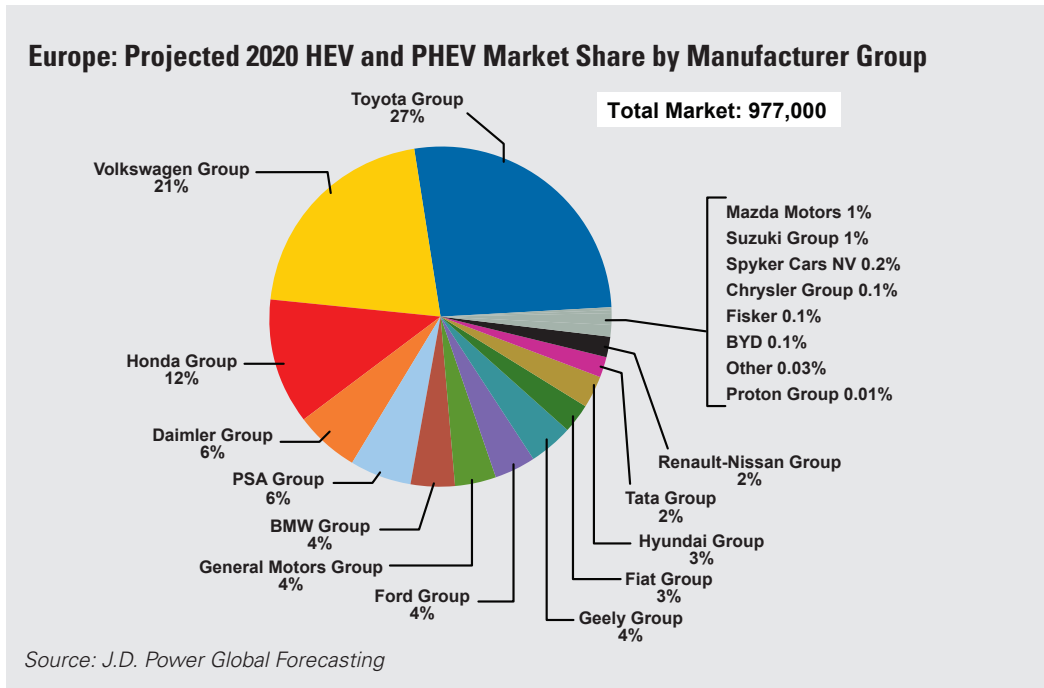
Europe: Number of Global HEV and PHEV Models per Year—2007-2020



Source: J.D. Power Global Forecasting



- A broader range of models in Europe will increase sales of HEVs to nearly 1.1 million units in 2020, which translates to a forecast of almost 4.1% of all passenger-vehicle sales in Europe and 29% of the 3.7 million HEVs forecasted to be sold globally in that year.
- Among the nearly three dozen competitors likely to offer HEVs in Europe in 2020, the top three—Toyota Group, Volkswagen Group, and Honda Group—are expected to account for about 65% of all sales.

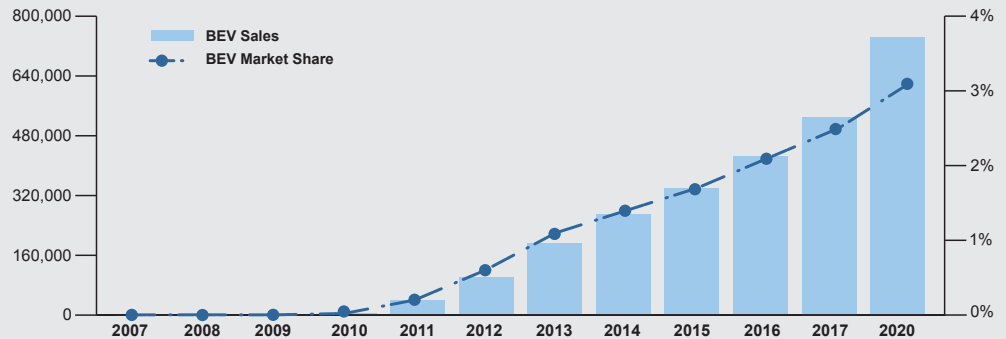


European Passenger-Vehicle Sales Outlook: BEVs

- Sales of BEVs in Europe reached just 330 units in 2009, and are expected to increase to 2,800 units in 2010. Sales are mostly low-volume fleet deliveries aimed at commercial users who find the limited driving range acceptable.
- Beginning in late 2010, the first of a new generation of BEVs will be available for personal use. The future success of these models (as with HEV models) will largely depend on their retail price, although they have not yet been announced. Incentives will also likely be required to reinforce even modest demand at the outset.
- J.D. Power is relatively bullish on future growth prospects for BEVs in Europe, especially with the European Union’s dedication to continued exhaust-emission reductions and fuel-economy improvement.
- As a result, sales of BEVs in Europe are forecasted to reach 742,000 units in 2020, representing 55% of the global total of BEV sales in that year.



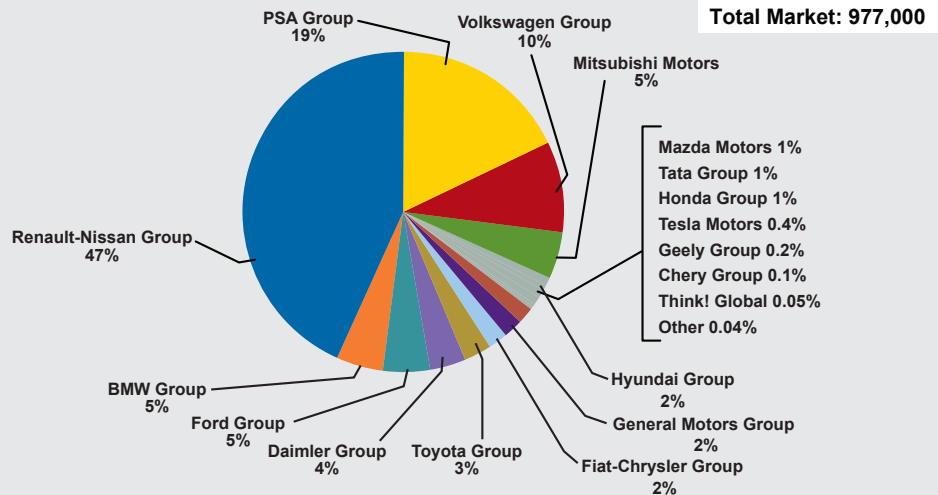
Europe: Sales of BEVs—2007-2020



Source: J.D. Power Global Forecasting

- Much of the future growth in Europe’s BEV sales can be attributed to the Renault-Nissan Group’s commitment to developing the Nissan Leaf BEV for markets in Europe, as well as globally.
- By 2020, the Renault-Nissan Group is expected to account for nearly half of all BEV sales in Europe, followed by the PSA Group and the Volkswagen Group, respectively.

Europe: Sales of BEVs by 2020



Source: J.D. Power Global Forecasting

Regulatory Environment in Europe

- In late 2008, the European Commission, along with the European Investment Bank, launched the European Green Cars Initiative with an initial budget of EUR 5 billion (US \$6 billion). The initiative is partly dedicated to supporting research and development of technology and infrastructure that will be essential to achieve breakthroughs in the use of renewable and non-polluting energy sources.
- In addition, this plan also supports member countries in their efforts to reduce the tax on new passenger vehicles that emit lower CO₂—which encourages the purchase of cleaner vehicles.



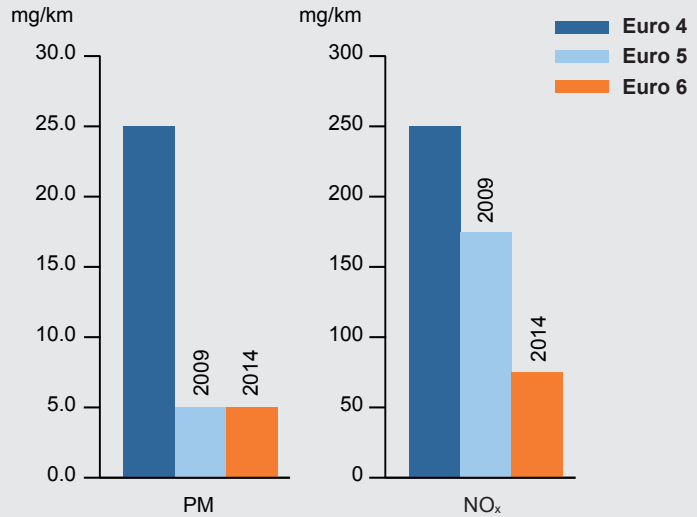
- With diesel-powered engines comprising a majority share of the European market, significant targets for reduction of diesel-engine emissions have been mandated for 2014 (Euro 6), which apply to all European Union member countries.

Noxious Emissions Reduction Mandates

- Mandated reduction in diesel engine emissions to become more severe at Euro 6 (2014). Legislation to be applied in all EU countries.
- Gasoline emissions—major measurements for CO and NO_x—already flattened at 60 mg/km of CO and new Euro 5 low level of 5 mg/km of PM for direct injection gasoline, with little anticipated future tightening.
- Majority hybrids use gasoline, but diesel hybrids (e.g., from PSA, M-B) may have significant vehicle price penalty.

Source: J.D. Power and Associates Research

Euro Tier Diesel Car Emissions



CO₂ Reduction Targets

Country CO ₂ Levels	2007	2008	Change
Average CO ₂	165	158	-4%

EU Policy		
Year	Target (CO ₂ g/km)	Percentage of Fleet Included
2012	130	65%
2013	130	75%
2014	130	80%
2015	130	100%
2020	95	100%

Fines for Missing Targets	
Grams above Target	Fine per Vehicle
1st	EUR 5
2nd	EUR 15
3rd	EUR 25
4th plus	EUR 95

Source: J.D. Power and Associates Research

- Regarding gasoline emissions in Europe, major measurements for carbon monoxide (CO) and nitrous oxide (NO_x) are already extremely low at 60 mg/km of CO. The Euro 5 limit for total hydrocarbon (HC) emissions is 100 mg/km.



Profile of HEV Consumers in Europe

Since the number of BEV buyers in Europe is limited, there is little information to develop a consumer profile; however, J.D. Power research regarding HEV buyers in Europe includes factors that help define their purchase behavior.

Demographics of HEV Buyers in Germany

- According to J.D. Power studies, HEV buyers are predominantly male (79%) by a much higher proportion than are buyers of gasoline-powered (53%) or diesel-powered (66%) vehicles. These HEV buyers are also older than all buyers (age 49 vs. age 40, respectively).
- More HEV buyers tend to have a higher level of education—50% have a university degree or a doctorate degree—and a majority (80%) are much more likely to be married, compared with all buyers (60%).
- The median household income of HEV buyers is 25% higher than among buyers of gasoline-powered vehicles (EUR 51,341 vs. EUR 41,906, respectively), but lower than diesel buyers (EUR 57,973).

Germany New-Vehicle Buyer Demographics (2010)

Gender	Gas Buyers	Diesel Buyers	Hybrid Buyers
Male	53%	66%	79%
Female	47%	34%	21%
Age	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Age	40	41	49
Education	Gas Buyers	Diesel Buyers	Hybrid Buyers
Abitur/Hochschulreife	28%	26%	23%
Universität/Fachhochschule	31%	37%	42%
Promotion (Doktor)	3%	4%	8%
Marital Status	Gas Buyers	Diesel Buyers	Hybrid Buyers
Married	52%	62%	80%
Single (Never Married)	37%	29%	17%
Household Income	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Income (Euros)	41,906	57,973	51,341

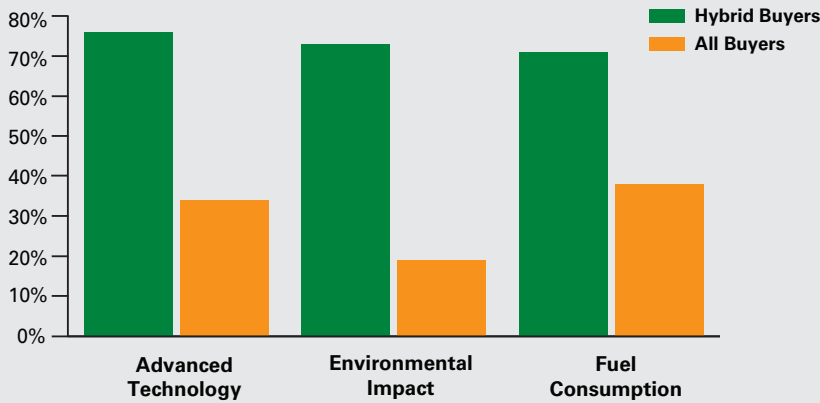
Source: J.D. Power and Associates 2010 Germany Vehicle Ownership Satisfaction StudySM (VOSS)

Purchase Behavior of HEV Buyers in Germany

- There are significant differences in purchase considerations between HEV buyers and all buyers in Germany:
 - The majority (75%) of HEV buyers indicate advanced technology is one of the most important factors in their purchase decision, compared with just 33% of all buyers.
 - In addition, like their counterparts in the US market, 72% of HEV buyers say environmental impact is one of the most important factors, compared with 18% of all buyers.
 - Nearly three-fourths (71%) of HEV buyers say fuel consumption is one of the most important factors, compared with 37% of all buyers.



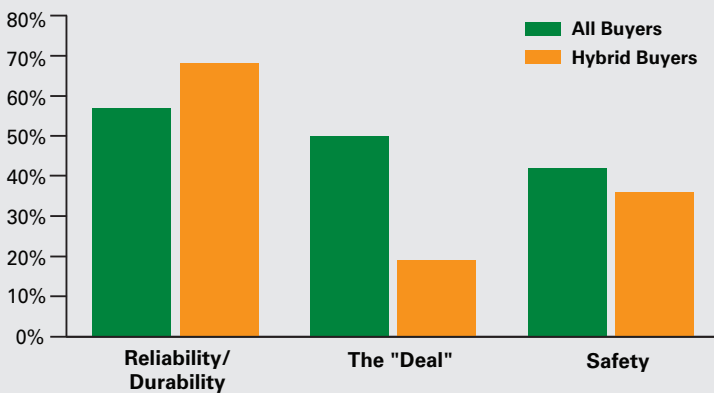
Top Three Most Important Factors in Choice of Make/Model, Hybrid Buyers vs. All Buyers



Source: J.D. Power and Associates 2010 Germany Vehicle Ownership Satisfaction StudySM (VOSS)

- There are no notable differences in the three most important factors for consideration among all buyers and HEV buyers:
 - Slightly more than one-half (56%) of all buyers cite reliability/durability as one of the most important factors for their purchase decision, compared with 67% of HEV buyers.
 - While nearly half (49%) of all buyers cite the deal they receive as a key purchase factor, just 18% of HEV buyers say the same.
 - Additionally, 42% of all buyers cite safety as one of the most important factors in their purchase, compared with just 36% of HEV buyers.

Top Three Most Important Factors in Choice of Make/Model, All Buyers vs. Hybrid Buyers



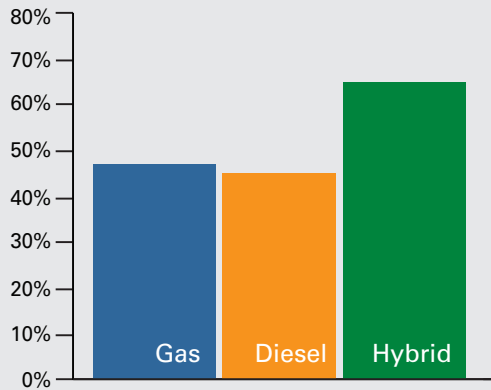
Source: J.D. Power and Associates 2010 Germany Vehicle Ownership Satisfaction StudySM (VOSS)



Other factors that affect the purchase decision of HEV buyers in Germany:

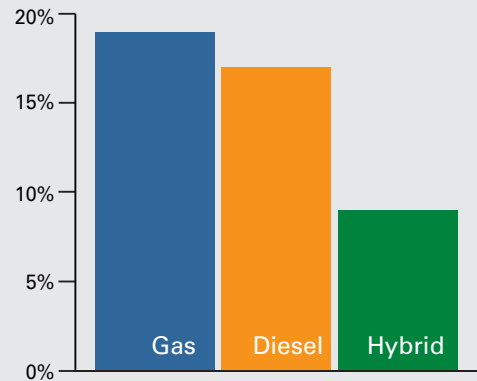
"I like to shop around before making a purchase"

(Agree Completely)



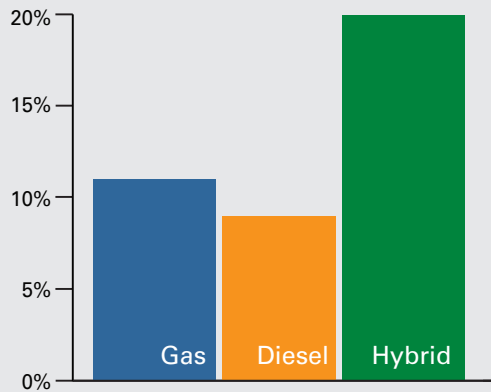
"When I find a brand I like, I stick to it"

(Agree Completely)



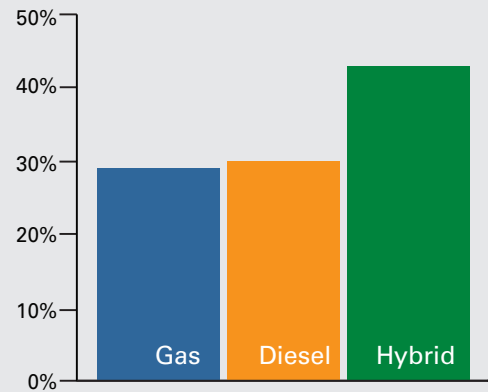
"I'm always one of the first of my friends to try new products or services"

(Agree Completely)



"I prefer to buy things my friends or neighbours would approve of"

(Disagree Completely)



Source: J.D. Power and Associates 2010 Germany Vehicle Ownership Satisfaction StudySM (VOSS)



Demographics of HEV Buyers in France

- Similar to HEV buyers in Germany, HEV buyers in France also are predominantly male (73%) by a much higher proportion than are buyers of gasoline-powered (53%) or diesel-powered (66%) passenger vehicles. HEV buyers are also significantly older than all buyers (a median age of 52 vs. 41, respectively).
- HEV buyers have more education—50% have higher than a university degree—than all buyers and are much more likely to be married (82% vs. 60% of all buyers).
- The median household income among HEV buyers is 20% higher than among buyers of gasoline-powered vehicles (median income of EUR 39,406 vs. EUR 32,550), and 10% higher than among buyers of diesel-powered vehicles (median income of EUR 36,159).

France New-Vehicle Buyer Demographics (2010)

Gender	Gas Buyers	Diesel Buyers	Hybrid Buyers
Male	40%	50%	73%
Female	60%	50%	27%
Age	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Age	42	41	52
Education	Gas Buyers	Diesel Buyers	Hybrid Buyers
Lycée/Enseignement Professionnel	29%	34%	17%
IUT/Université	28%	28%	21%
Enseignement Supérieur	37%	34%	50%
Marital Status	Gas Buyers	Diesel Buyers	Hybrid Buyers
Married	55%	68%	82%
Single (Never Married)	33%	23%	7%
Household Income	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Income (Euros)	32,550	36,159	39,406

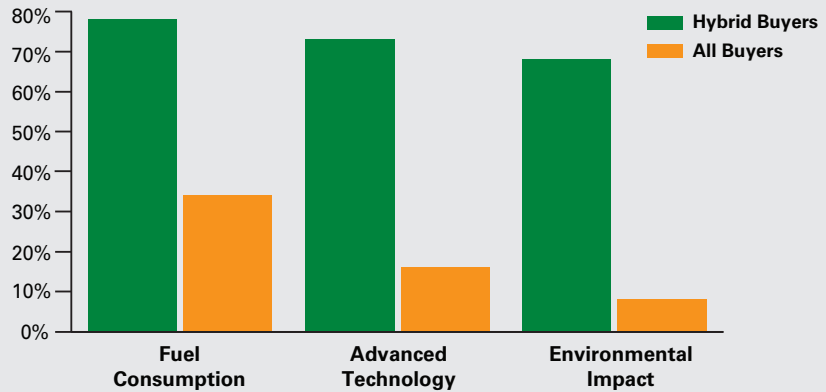
Source: J.D. Power and Associates 2010 France Vehicle Ownership Satisfaction StudySM (VOSS)

Purchase Behavior of HEV Buyers in France

- The three most important factors for HEV buyers in France in making a purchase decision are significantly different from those factors most important to all buyers:
 - A majority (78%) of HEV buyers say fuel consumption is one of the most important factors, compared with 35% of all buyers.
 - Nearly three-fourths (73%) of HEV buyers say advanced vehicle technology is one of the most important factors, compared with just 16% of all buyers.
 - While 69% of HEV buyers say environmental impact is one of the most important factors, only 8% of all buyers say the same.



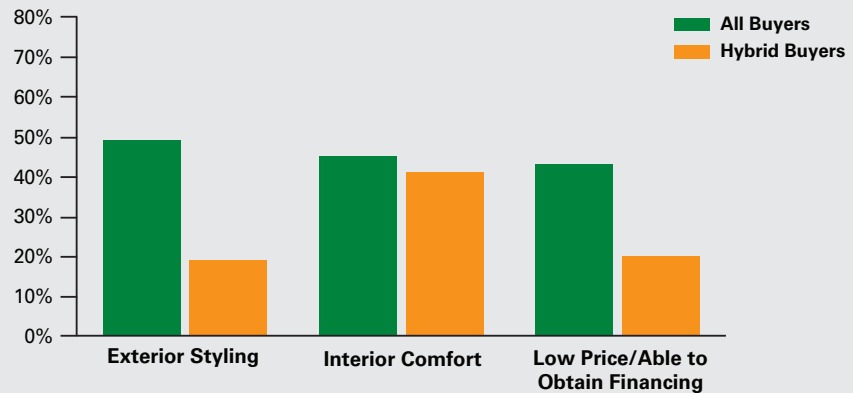
Top Three Most Important Factors in Choice of Make/Model, Hybrid Buyers vs. All Buyers



Source: J.D. Power and Associates 2010 France Vehicle Ownership Satisfaction StudySM (VOSS)

- The three most important purchase factors for all buyers are notably different from those cited by HEV buyers:
 - Nearly one-half (48%) of all buyers cite exterior styling as one of the most important factors for their purchase, compared with just 19% of HEV buyers.
 - Approximately 45% of all buyers say interior comfort is a key purchase factor, compared with 41% HEV buyers who say this is a key factor.
 - In addition, 43% of all buyers cite low price/ability to obtain financing as one of the most important factors, while only 19% of HEV buyers say the same.

Top Three Most Important Factors in Choice of Make/Model, All Buyers vs. Hybrid Buyers

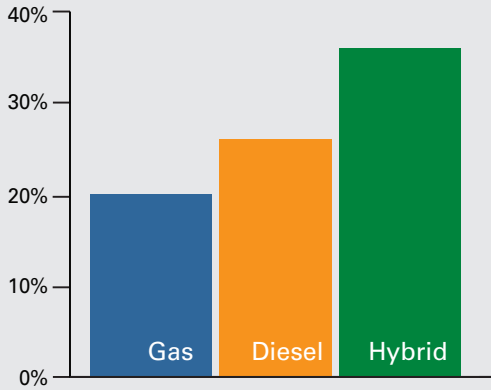


Source: J.D. Power and Associates 2010 France Vehicle Ownership Satisfaction StudySM (VOSS)

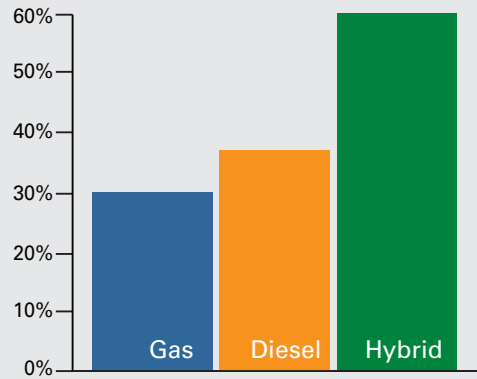


Other factors that affect the purchase decision of HEV buyers in France:

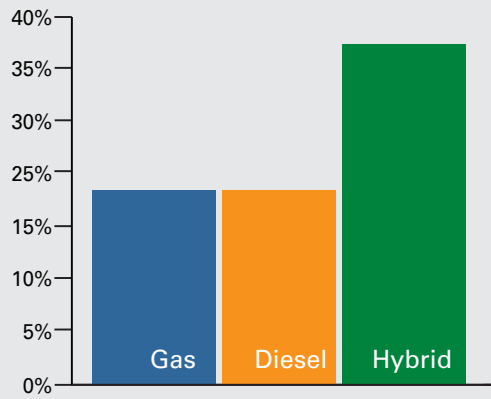
"Fun to drive"
(vs. "Ordinary to drive")



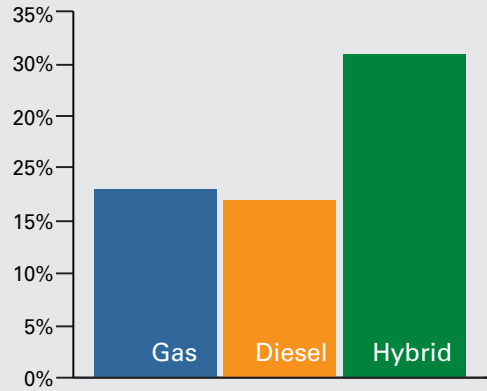
"Reliable"
(vs. "Unreliable")



"I'm always one of the first of my friends to try new products or services"
(Agree Completely or Agree Somewhat)



"I prefer to buy things my friends or neighbours would approve of"
(Agree Completely or Agree Somewhat)



Source: J.D. Power and Associates 2010 France Vehicle Ownership Satisfaction StudySM (VOSS)

**Demographics of HEV Buyers in the United Kingdom (UK)**

- As in Germany and France, HEV buyers in the UK are more predominantly male (70%), compared with buyers of gasoline-powered vehicles (50%). These HEV buyers are also older than all buyers (median age of 56 vs. 49, respectively).
- HEV buyers have a higher level of education: 67% have either a university or postgraduate degree, compared with 57% of buyers of diesel-powered vehicles and 51% of buyers of gasoline-powered vehicles. However, the proportions of both HEV buyers and all buyers in the UK who are married are similar, unlike in Germany and France.
- The median household income of HEV buyers is much higher than that of all buyers of gasoline-powered and diesel-powered vehicles. Median household income of HEV buyers is 45% higher than that of buyers of gasoline-powered vehicles (GBP 54,881 vs. GBP 37,776), and 6% higher than that of buyers of diesel-powered vehicles (GBP 51,707).

UK New-Vehicle Buyer Demographics (2010)

Gender	Gas Buyers	Diesel Buyers	Hybrid Buyers
Male	50%	70%	70%
Female	50%	30%	30%
Age	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Age	49	49	56
Education	Gas Buyers	Diesel Buyers	Hybrid Buyers
Trade/Vocational College	19%	19%	14%
University/Polytechnic	32%	35%	42%
Postgraduate Degree/Studies	19%	22%	25%
Marital Status	Gas Buyers	Diesel Buyers	Hybrid Buyers
Married	66%	78%	75%
Single (Never Married)	22%	14%	10%
Household Income	Gas Buyers	Diesel Buyers	Hybrid Buyers
Median Income (GBP)	37,776	51,707	54,881

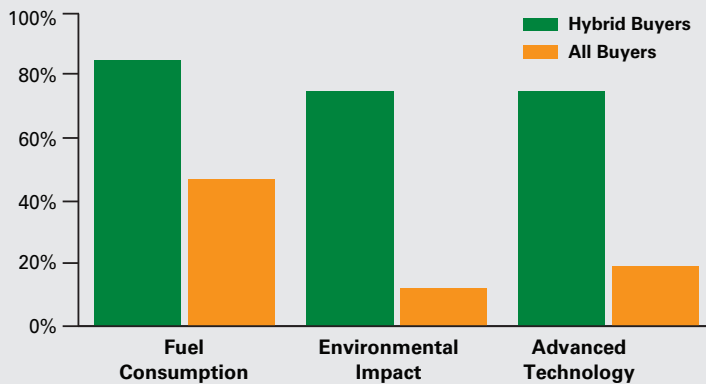
Source: J.D. Power and Associates 2010 UK Vehicle Ownership Satisfaction StudySM (VOSS)



Purchase Behavior of HEV Buyers in the UK

- Similar to Germany and France, there are significant differences in the UK in the most important factors in a purchase decision between HEV buyers and all buyers:
 - A majority (84%) of HEV buyers say fuel consumption is one of the most important factors, compared with 47% of all buyers.
 - Approximately 75% of HEV buyers say environmental impact is one of the most important factors, which is much higher than the 12% of all buyers.
 - In addition, 74% of HEV buyers say advanced technology is one of the most important factors, compared with just 19% of all buyers.

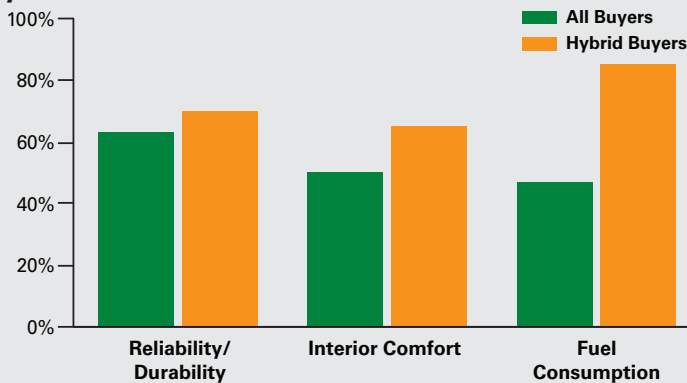
Top Three Most Important Factors in Choice of Make/Model, Hybrid Buyers vs. All Buyers



Source: J.D. Power and Associates 2010 UK Vehicle Ownership Satisfaction StudySM (VOSS)

- The most important consideration factors among HEV buyers in the UK are somewhat different, compared with all buyers:
 - Nearly three-fourths (63%) of all buyers cite reliability/durability as one of the most important factors for their purchase, compared with nearly 69% of HEV buyers.
 - While 49% of all buyers cite interior comfort as a key purchase factor, nearly 65% of HEV buyers say the same.
 - Only 47% of all buyers cite fuel consumption as one of the most important factors in their purchase decision, while 84% of HEV buyers say the same.

Top Three Most Important Factors in Choice of Make/Model, All Buyers vs. Hybrid Buyers

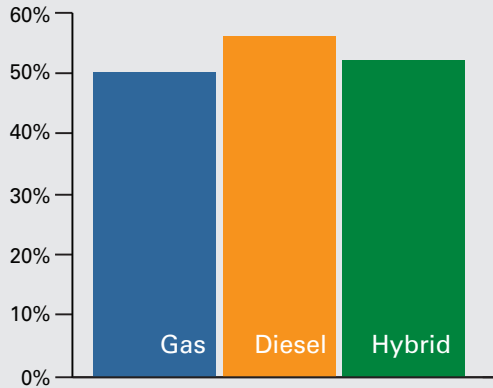


Source: J.D. Power and Associates 2010 UK Vehicle Ownership Satisfaction StudySM (VOSS)

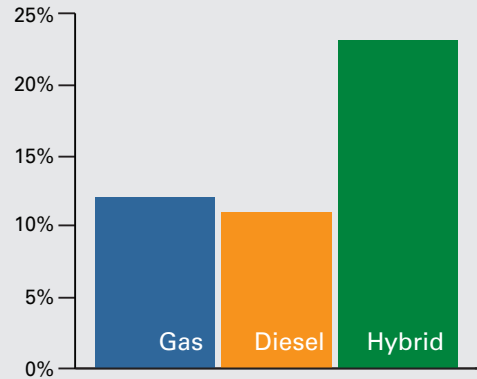


Other factors that affect the purchase decision of HEV buyers in the UK:

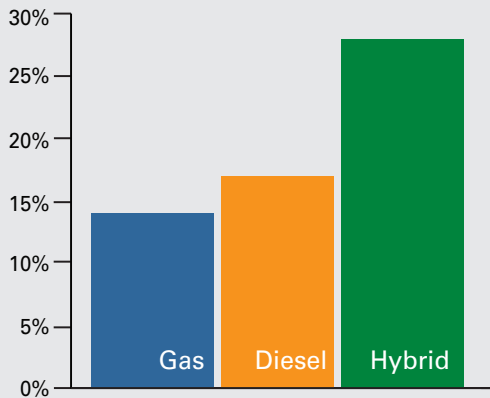
"I like to shop around before making a purchase"
(Agree Completely)



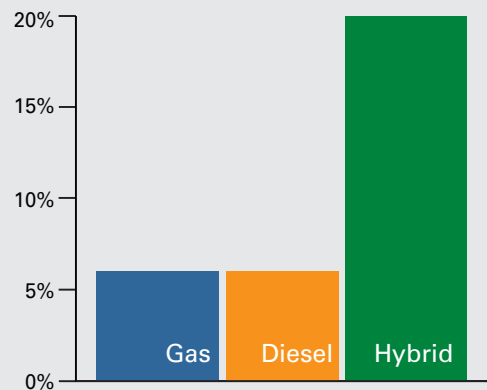
"When I find a brand I like, I stick to it"
(Agree Completely)



"If a product is made by a company I trust, I'll buy it even if it's slightly more expensive"
(Agree Completely)



"I'm always one of the first of my friends to try new products or services"
(Agree Completely)



Source: J.D. Power and Associates 2010 UK Vehicle Ownership Satisfaction StudySM (VOSS)



Conclusion

Due to strong public opinion and government action, Europe is—and will continue to be—a leader in the transition or migration to alternative-energy vehicles, including HEVs and BEVs.

With Europe's greater emphasis on greenhouse gases, compared with other industrialized markets, the sources and processes to generate electricity for BEVs could be of greater importance in Europe, and could require major growth in the development of alternative-energy sources, such as wind, solar, and nuclear power.

Because vehicle owners in many European Union member countries are taxed on their vehicle's carbon footprint, Europe may provide a credible testing ground should there be a movement to examine the emissions of BEVs from well to wheel. Europe may well become the pilot region for creating commercial and passenger fleets of green vehicles.



Battery-Based Technologies

Japan

“The new Japanese government has set a very ambitious target for a greenhouse gas emissions reduction of 25% by 2020, if compared to the 1990 level. It has also made it clear that it is prepared to provide more financial and technical assistance to developing countries than in the past. ... Japan announced this ambitious pledge because it wishes to serve as a ‘bridge’ among countries with varied interests and to preserve the planet for future generations.”

—Japan Former Prime Minister Yukio Hatoyama, September 24, 2009

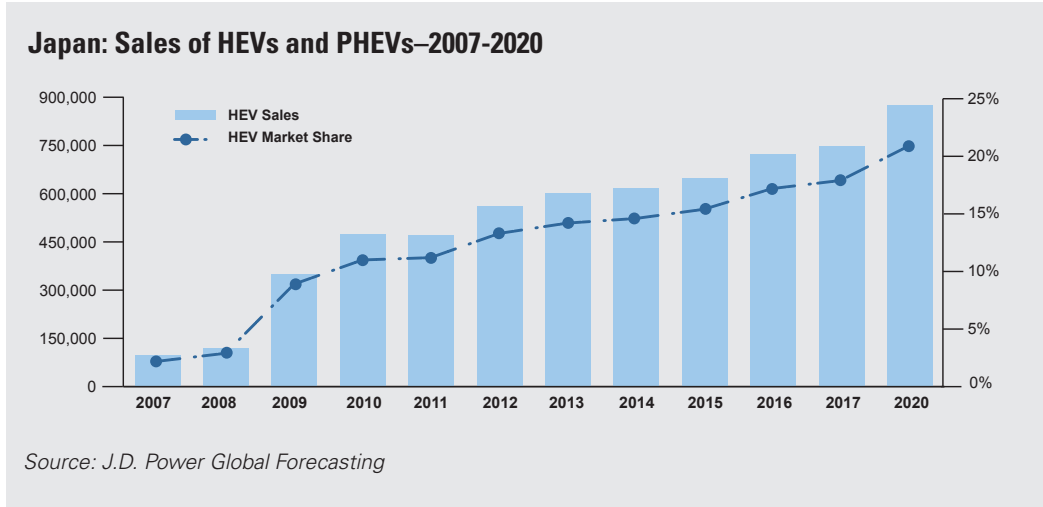
Overview

- Due to the engineering efforts of both the Toyota Group and the Honda Group, with the support of the Japanese government, Japan has been the recognized leader in hybrid electric vehicle (HEV) technology development since the first mass production vehicles were introduced in the late 1990s.
- Although the United States was the largest market for HEVs since the late 1990s, Japan surpassed it in HEV sales in 2009. This was due in large part to the runaway success of the new Toyota Prius, which was launched in Japan in 1997 before going on sale in the United States.
- In 2009, combined sales of HEVs, including plug-in electric vehicles (PHEVs), reached more than 348,000 units, and the country is on pace to reach 475,000 HEV sales in 2010. This would mean that HEVs will account for more than 10% of all passenger vehicles sold in Japan in 2010, and that Japan would achieve the highest HEV penetration of any of the largest passenger-vehicle markets in the world.

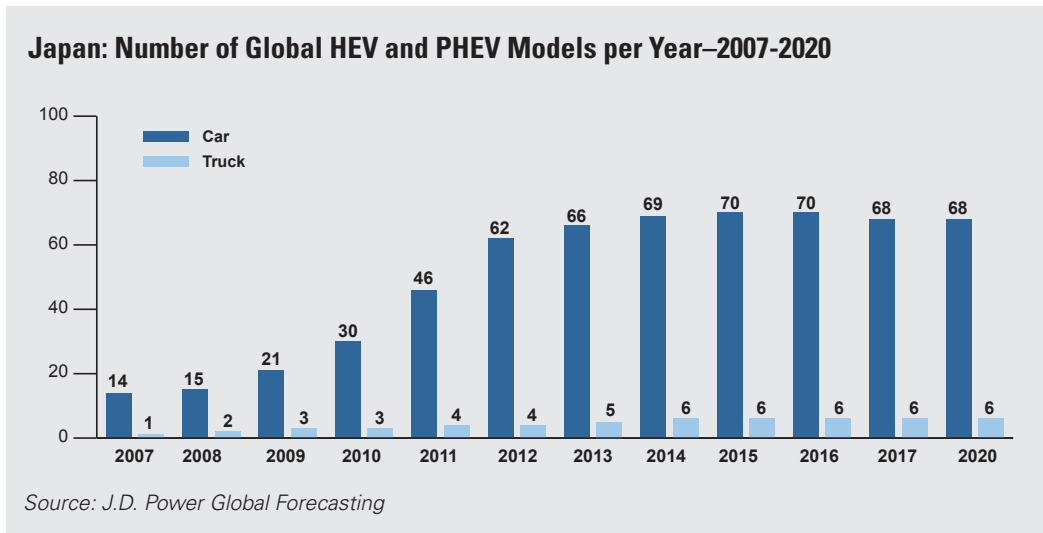


Japanese Passenger-Vehicle Sales Outlook: HEVs

- Sales of HEVs grew by nearly 30% in 2009, due mostly to the introduction of new models. Going forward, sales of HEVs are expected to grow at a slower pace, as the demographic segment targeted for HEV purchases will begin to reach saturation.
- By 2020, HEV sales are expected to reach nearly 875,000 units, which would represent 20% of the 4.2 million total passenger-vehicle sales forecasted for 2020, or approximately 22% of the total hybrid vehicles sold globally.

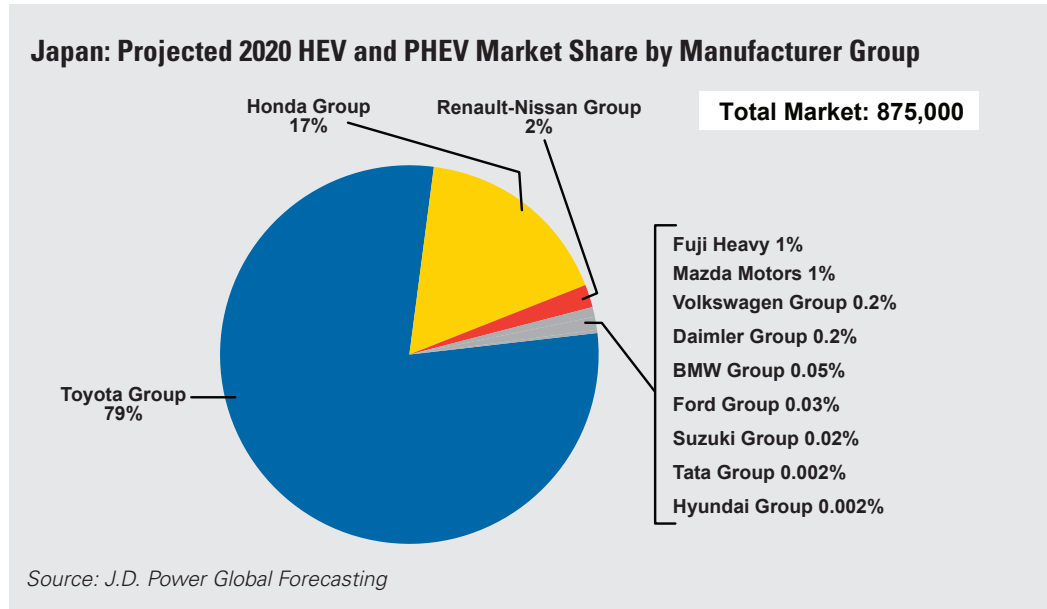


- The number of HEV models produced and sold during the next decade is expected to increase from approximately 33 models in 2010 to more than 70 in 2020. However, many of these models are expected to sell in small volumes.





- HEV models produced and sold by the Toyota Group and Honda Group comprise the majority of hybrids sold in Japan in 2010, and are forecasted to account for nearly 96% of all hybrids sold in that country in 2020.

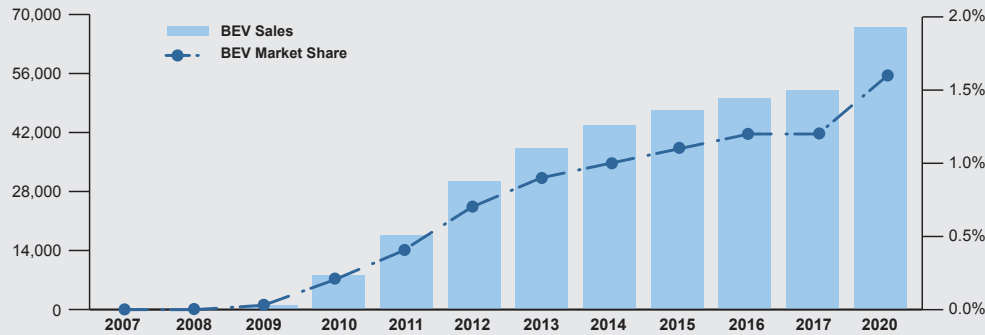


Japanese Passenger-Vehicle Sales Outlook: BEVs

- The battery electric vehicle (BEV) market in Japan is currently very small, despite all the media attention and the wide array of BEV concept vehicles displayed by Japanese automakers at auto shows around the world. J.D. Power expects the alternative-vehicle market in Japan to be dominated by HEVs, rather than BEVs, during the next decade.
- While Japan has established a leadership position in BEV technology development, it has not necessarily translated into influencing Japanese consumers to seek out BEVs to replace their traditional ICE- or HEV-powered vehicles.
- Due to Japan's population density and size, rail transportation continues to play a significant role in the country and is so entrenched in the culture that in some areas it is the primary source of transportation, rather than private vehicles.
- BEVs remain too expensive for consumers in Japan and have too narrow a driving range to sell in significant numbers. While BEV sales in 2009 were less than 1,000 units, this is expected to increase substantially in 2010 to nearly 10,000 units, and to account for 67,000 units in 2020.



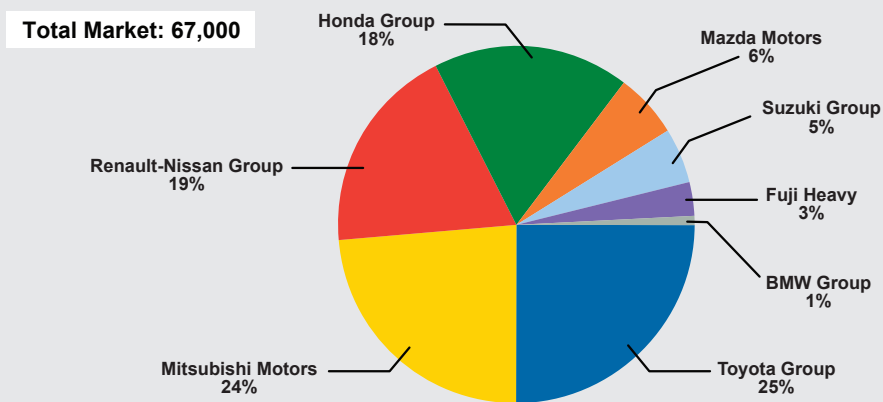
Japan: Sales of BEVs—2007-2020



Source: J.D. Power Global Forecasting

- The Renault-Nissan Group and Mitsubishi Group are currently the leaders in BEV technology in Japan, and J.D. Power expects the Nissan Leaf BEV to be sold in that country, as well as in the United States.
- The Toyota, Honda, and Fuji Heavy Industries groups are expected to develop their own BEV models in the next 2 to 3 years. Foreign manufacturers, such as the Volkswagen Group and Ford Group, have also made commitments to develop BEVs in Japan, and both automaker groups are expected to offer electric vehicles in that country by 2014.

Japan: Projected 2020 Sales of BEVs



Source: J.D. Power Global Forecasting

- On the other hand, the same population density that makes rail so viable could also prove to be a good first-case scenario for alternatives to battery-range extension. In April 2010, California-based environmental startup Better Place announced that it would be launching the first tests of its battery-swapping concept in BEV taxis in Tokyo in partnership with the Japanese Ministry of Economy, Trade and Industry and Tokyo’s largest taxi operator.



Regulatory Environment in Japan

- Japan's automotive regulatory environment is among the strictest in the world. The National Agency of Vehicle Inspection is responsible for administering a mandatory periodic maintenance inspection of all passenger vehicles.
- This inspection, known as *shaken*, which includes testing the vehicle's emissions, begins following the first 3 years of new-vehicle ownership and is conducted every 2 years thereafter. Although the administrative fee for the *shaken* is approximately JPY 1,500 (US \$17), the total fee, including the testing, parts, recycling, etc., can range from JPY 40,000 to JPY 70,000 (US \$450 to US \$780).
- This inspection process may conclude that some vehicles are no longer roadworthy, at which point they would be scrapped or sold to neighboring Asian countries. This testing process allows Japan to maintain a national vehicle fleet that operates at near optimal performance, which makes the country's tailpipe emissions among the lowest in the world.
- In addition to the *shaken*, Japanese vehicle owners also pay two progressive vehicle taxes: a weight tax (at time of purchase) and an annual road tax. The owner burden of both of these taxes is correlated with the size of the vehicle's engine. Annual road taxes in Japan for 2010 range from JPY 3,000 to JPY 32,000 (US \$33 to US \$360) and weight taxes from JPY 55,000 to JPY 75,000 (US \$619 to US \$844).
- While taxation is an effective tool to modify purchase behavior for cleaner vehicles, the Japanese government has also implemented aggressive fuel-efficiency targets. The target for 2015 is a 23.5% improvement, compared with 2004 levels, and would apply to vehicles with a GVW less than or equal to 2.5 tons. To help meet this target, tax incentives and subsidies, among other incentives, are provided for replacing older, less fuel-efficient vehicles with those that meet or exceed the 2010 standard.

Government Policy

- Japan is making serious efforts to reduce carbon dioxide emissions. The Japanese government estimates that 20% of CO₂ emissions are generated by the road transportation sector, and 90% of that is auto-related.
- The target for fuel economy in 2010 is a 23% increase in efficiency, compared with the 1995 level. The target for 2015 is a 23.5% improvement from the 2004 level. These rules apply to vehicles with a GVW less than or equal to 2.5 tons.
- In 2009, the government provided tax incentives for buyers of vehicles with good fuel economy. New vehicles with emissions that are 75% less than the 2005 standard were subject to a lower rate of tax.
- A new passenger car with 15% better fuel economy than the 2010 standard receives a JPY 100,000 (US \$1,125) tax subsidy. The Japanese government allocated JPY 370 billion (US \$4.16 billion) to this program.
- The following vehicles are classified as alternative energy/low emission vehicles: FCEVs, BEVs, HEVs, natural gas vehicles, and methanol vehicles.



Profile of HEV Buyers in Japan

Since the number of BEV buyers in Japan is limited, there is little information to develop a profile about them; however, J.D. Power research identifies factors that help shape the purchase behavior of HEV buyers in Japan.

Demographics

- According to J.D. Power research, HEV buyers in Japan are older than their gasoline- and diesel-buying counterparts. Nearly three-fourths (72%) are age 40 or older. In comparison, 56% of buyers of gasoline-powered vehicles are age 40 or older, as are 23% of buyers of diesel-powered vehicles.
- Slightly more than half (57%) of HEV buyers in Japan are married, compared with approximately 50% of all buyers in Japan.
- As in the United States and in Europe's largest countries, HEV buyers in Japan have significantly higher income than do their counterparts who purchase gasoline- and diesel-powered vehicles. Slightly less than half (46%) of HEV buyers report an annual pre-tax income of JPY 10 million or more, compared with just 12% for buyers of gasoline-powered vehicles and 23% of diesel-powered vehicles.

Japan New-Vehicle Buyer Demographics (2010)

Age	Gas Buyers	Diesel Buyers	Hybrid Buyers
20s or under	10%	23%	4%
30s	34%	54%	24%
40s	32%	0%	29%
50s	16%	0%	25%
60s or older	8%	23%	18%
Marital Status	Gas Buyers	Diesel Buyers	Hybrid Buyers
Married	49%	54%	57%
Unmarried	51%	46%	43%
Household Income	Gas Buyers	Diesel Buyers	Hybrid Buyers
< JPY 6M	50%	36%	23%
JPY 6M-10M	30%	35%	31%
> JPY 10M	12%	23%	46%

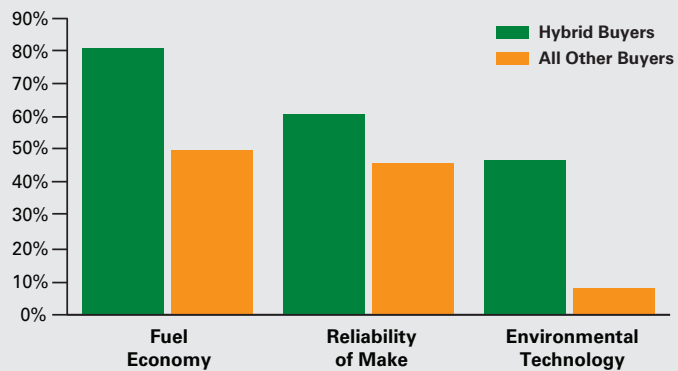
Source: J.D. Power and Associates 2009 Japan Sales Satisfaction Index (SSI) StudySM



Purchase Behavior of HEV Buyers in Japan

- Different factors influence the purchase decisions of HEV buyers, compared with those of all buyers in Japan.
 - While 81% of HEV buyers say fuel economy is one of the most important factors, just 50% of all buyers say the same.
 - Slightly more than half (61%) of HEV buyers say the reliability of the make is one of the most important factors, compared with just 46% of all buyers.
 - A higher percentage of HEV buyers (46%) say environmental technology is one of the most important factors, compared with just 8% of all buyers.

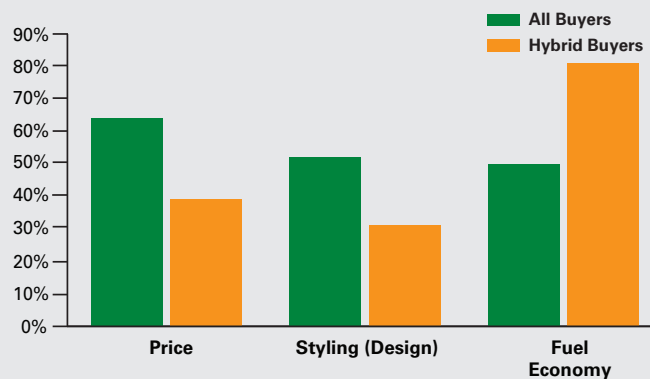
Before Shopping, What Are the Three Most Important Purchasing Criteria? Hybrid Buyers vs. All Other Buyers



Source: J.D. Power and Associates 2009 Japan Sales Satisfaction Index (SSI) StudySM

- The factors that most influence the vehicle-purchase decision differ among buyers. Some of the most notable differences are:
 - More than 63% of all buyers cite price as one of the most important factors for their purchase, compared with just 39% of HEV buyers.
 - Approximately 52% of all buyers cite vehicle styling as a key purchase factor, compared with just 31% of HEV buyers.
 - One-half (50%) of all buyers cite fuel economy as one of the most important factors in their purchase, which is much lower than the 81% of HEV buyers.

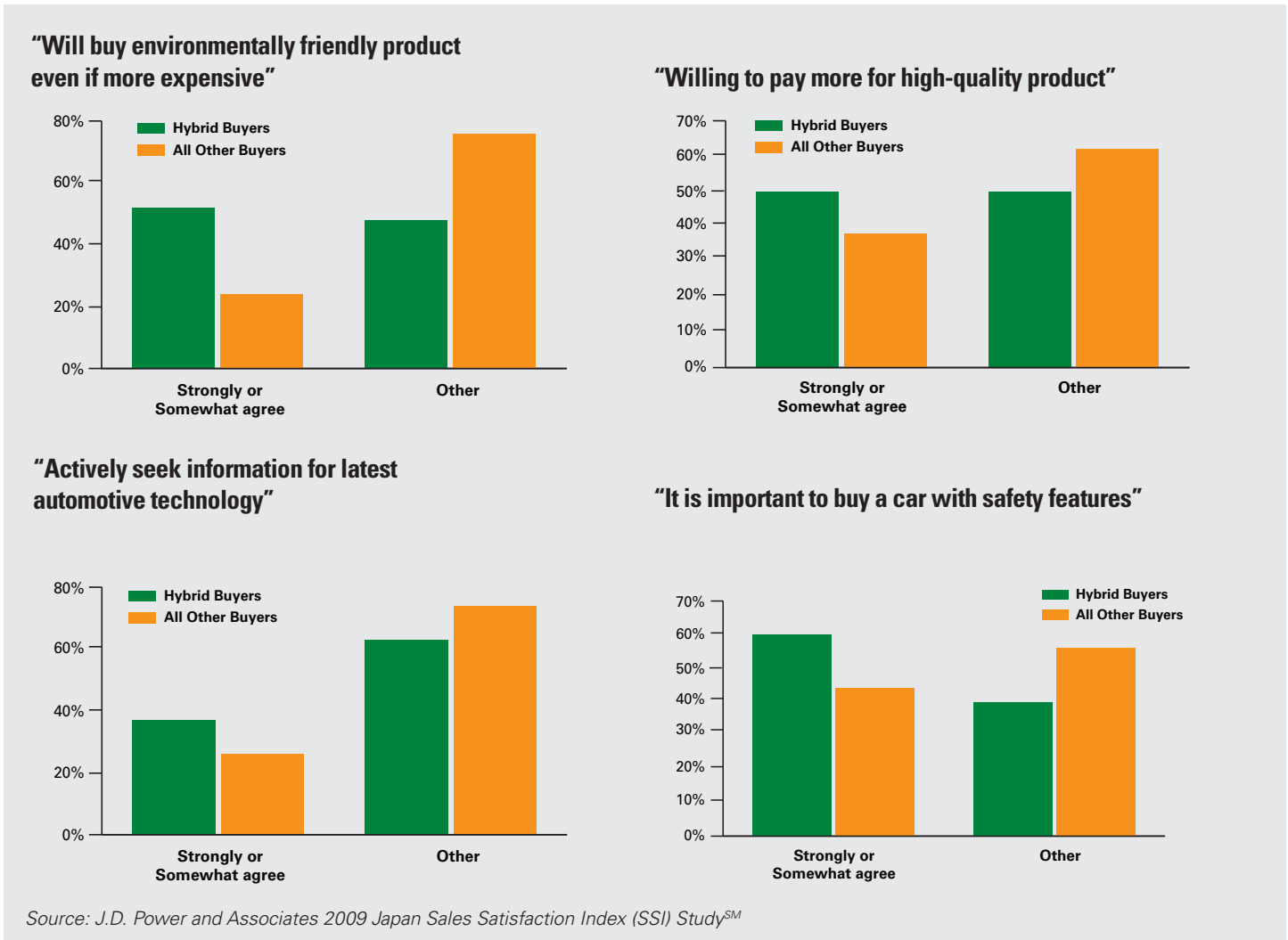
Before Shopping, What Are the Three Most Important Purchasing Criteria? All Buyers vs. Hybrid Buyers



Source: J.D. Power and Associates 2009 Japan Sales Satisfaction Index (SSI) StudySM



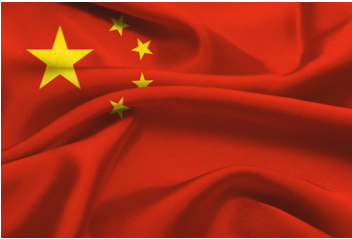
Other factors that affect the purchase decision of HEV buyers in Japan:



Conclusion

Of the four major automotive markets examined in this report, Japan, due to its compact geographic size and highly populated urban regions, is likely best-suited to address both the driving range issue associated with BEVs, as well as to create an effective infrastructure necessary for widespread BEV adoption.

Despite Japan’s apparent promise as a BEV market, J.D. Power forecasts that BEV sales will be minimal by 2020. The major challenges facing BEV sales are the presence of advanced HEVs in the market; the anticipated advancements in HEV technology; the existing mandatory *shaken* testing of vehicles, which allows only the best-performing vehicles on the road; and the prominence and effectiveness of rail transportation.



Battery-Based Technologies

China

“Global climate change has a profound impact on the survival and development of mankind. It is a major challenge facing all countries. ... We will intensify our effort to conserve energy and improve energy efficiency. We will endeavor to cut carbon dioxide emissions per unit of GDP by a notable margin by 2020.”

—People’s Republic of China President Hu Jintao, September 23, 2009

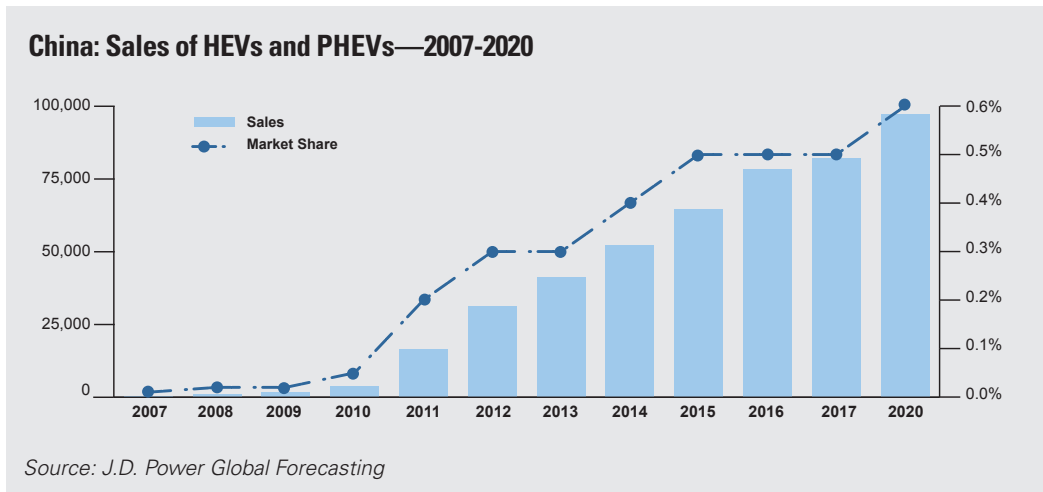
Overview

- China now boasts the largest vehicle market in the world, the second-largest economy in the world, and is the second-largest consumer of crude oil in the world, as well as being the world’s largest producer of CO₂ emissions.
- Given China’s rapid economic and industrial growth during the past two decades—and the continued growth forecasted for the coming years—the country must explore means to limit its energy consumption, as well as pollution caused by vehicle emissions.
- To that end, in mid-2010 the government announced plans to invest RMB 100 billion (US \$15 billion) to help domestic automakers put 20 million clean and fuel-efficient vehicles on China’s roads by 2020.
- If successful, these 20 million vehicles would represent approximately 10% of the 200 million light vehicles expected to be in operation in China by 2020.
- However, the limited success that other leading automotive nations have achieved in transitioning their national vehicle fleets to hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) may not bode well for China’s plans. In addition, the electricity to power BEVs and plug-in electric vehicles (PHEVs) would most likely be generated by burning coal, which China has in abundance, but which would only transfer the emissions from vehicle tailpipes to power plants.

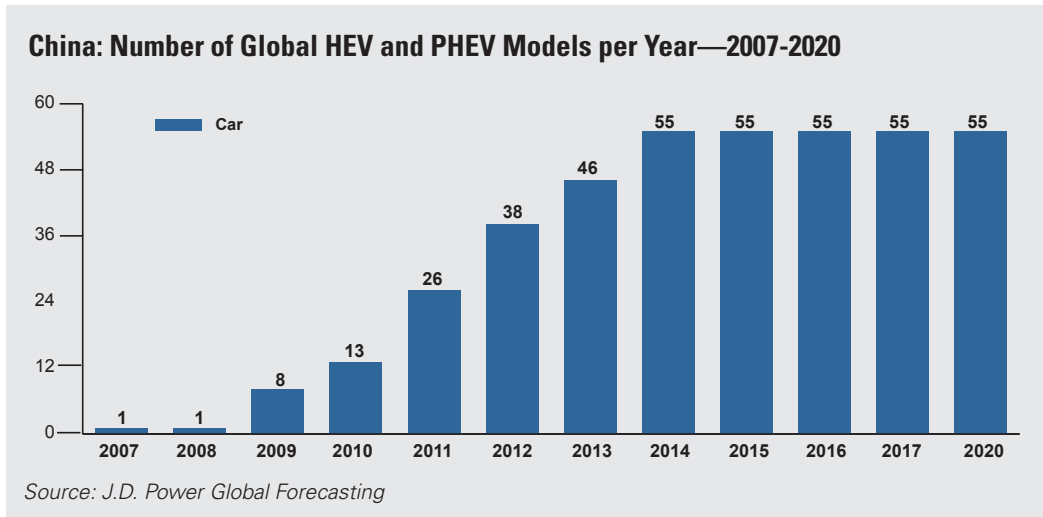


Chinese Passenger-Vehicle Sales Outlook: HEVs

- In 2009, combined sales of HEVs, which included PHEVs, in China reached just 1,883 units, or less than 0.10% of all passenger vehicles sold in that country. In 2010, sales of HEV/PHEVs are expected to climb to just 3,280 units, which continues to translate to less than 1% of all passenger-vehicle sales.
- J.D. Power forecasts sales of HEV/PHEVs in China will reach 80,000 units by 2020, which would represent 5% of passenger-vehicle sales forecasted for 2020. This is significantly lower than the 20 million vehicles projected by the Chinese government. For China to reach its stated goals, the market will likely need support from government policy (in the form of taxation on traditional vehicles or subsidies for alternative-energy vehicles), or there would need to be a technology breakthrough that makes HEVs more affordable and attractive to consumers.



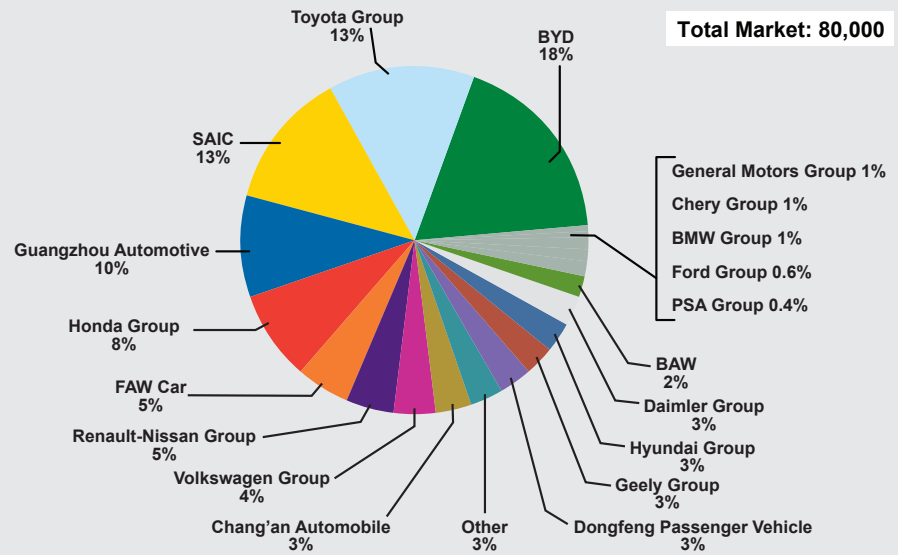
- Sales of HEVs are expected to increase due to the launch of many more models. The number of HEV models in China is expected to grow from just eight in 2009 to as many as 55 by 2015. However, it will likely be difficult for most automakers to sell these vehicles profitably without some form of government assistance.





- By 2020, there will be more than two dozen manufacturers building and selling HEVs in China, but only the five largest automaker groups will account for 65% of all sales.

China: Projected 2020 HEV and PHEV Market Share by Manufacturer Group

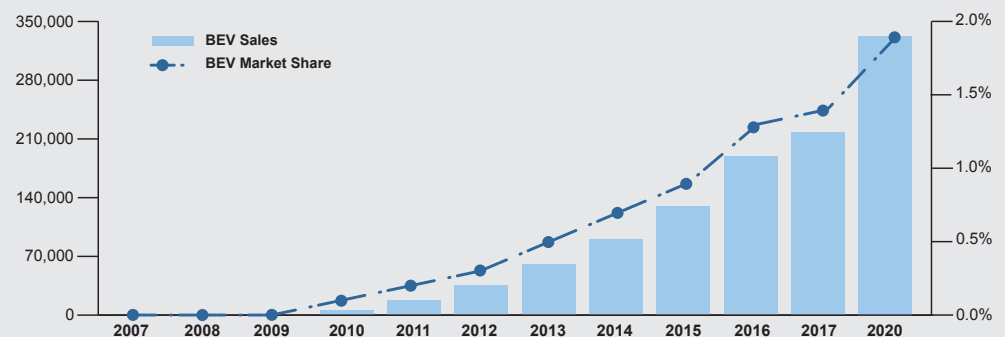


Source: J.D. Power Global Forecasting

Chinese Passenger-Vehicle Sales Outlook: BEVs

- Currently, the Chinese government is focused on the development of BEVs, and as a result Chinese automakers are concentrating on this type of vehicle. A number of new BEV models will launch in 2010, and more models will launch during the next few years. However, key hurdles must be overcome before BEVs will become widely accepted, both in terms of technology and cost.
- While BEV sales were practically non-existent in 2009, they are expected to reach 5,100 units in 2010, and climb to 128,000 units annually by 2015 and to 332,000 units by 2020. This would push BEV sales ahead of those in both the United States and Japan, but would still be behind Europe in 2020.

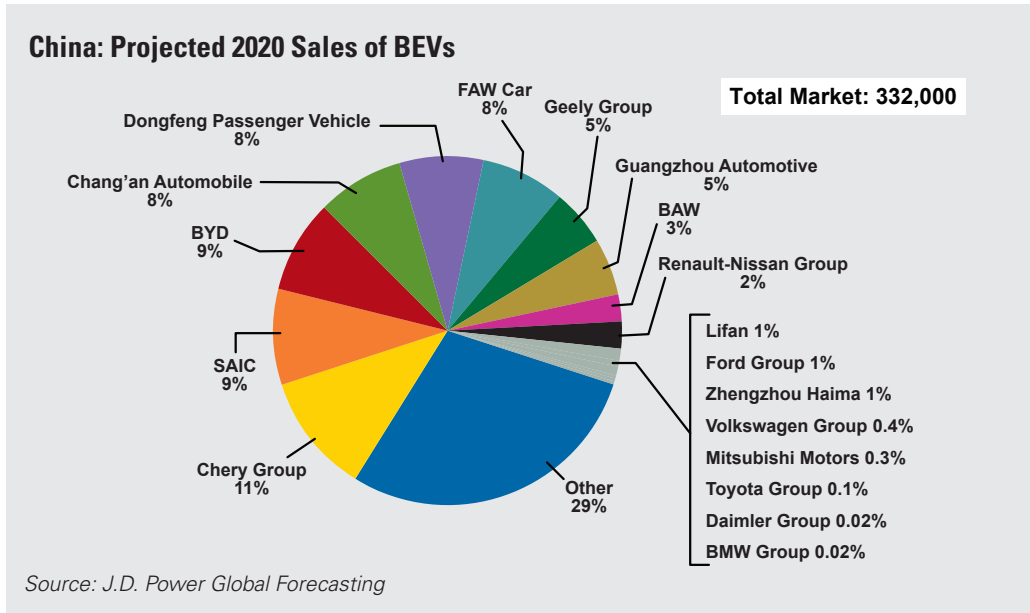
China: Sales of BEVs—2007-2020



Source: J.D. Power Global Forecasting



- By 2020, there will be more than 20 manufacturer groups building and selling battery electric vehicles in China, which will result in small BEV sales volumes and make it difficult for some manufacturers to earn a profit.



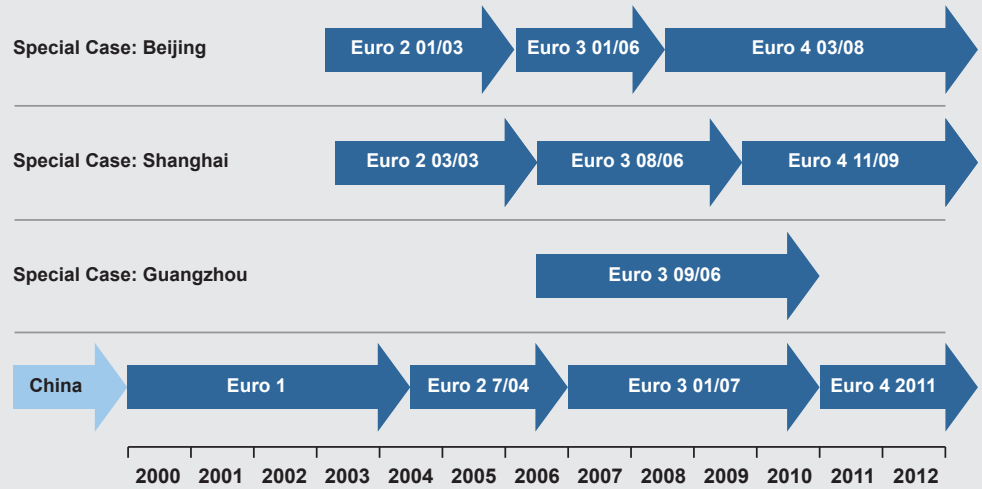
Regulatory Environment in China

- As noted earlier, China wants to have 20 million battery-based vehicles on its roads by 2020, which equates to 15 million HEVs and 5 million BEVs. To meet this goal, the government has set aside nearly RMB 100 billion (US \$15 billion) to support domestic Chinese automakers in developing alternative-energy vehicles and to provide funds to encourage the production of more fuel-efficient vehicles powered by traditional ICEs.
- China has written its own set of emissions regulations, which are based closely on European Union regulations. At present, automakers are required to meet the equivalent of Euro 3 emissions regulations; Euro 4 regulations will be required at the beginning of 2011. In China's two largest cities, Beijing and Shanghai, the equivalent of Euro 4 standards have already been introduced, in March 2008 and November 2009, respectively.
- Although the EU-based exhaust-emissions standards have been used in China for the past 10 years, it was only in 2007 that the Ministry of Environmental Protection was created, which should help accelerate the drive to greener vehicle alternatives, in particular regarding policy formation and enforcement of regulations.
- While gasoline prices are subsidized, the government also enforces progressive taxes on vehicle manufacturers, which are based on engine size and escalate from 1% to 12% for engines up to 3.0 liters. For even larger engines, these taxes can exceed 40%.
- The sales tax on vehicles is also a progressive duty tax. Vehicles with engine sizes less than 1.6 liters are taxed at 7.5%, and all other vehicles with more than 1.6-liter engines are taxed at 10%. Subsidies of up to RMB 50,000 (US \$7,350) are provided for HEVs, and as much as RMB 60,000 (US \$8,800) for BEVs.
- Although financial subsidies for HEVs and BEVs can offset the purchase price, price is not a top-of-mind priority among alternative-vehicle intenders in China. To help jump-start sales of PHEVs and BEVs, the government in China has committed to running a pilot program in 13 cities, with a goal of building infrastructure (charging stations) to meet the needs for these new energy vehicles (NEVs).

China wants to have 20 million battery-based vehicles on its roads by 2020, which equates to 15 million HEVs and 5 million BEVs.



Emission Standard Time Line



Source: J.D. Power and Associates Research

Government Targets

Policy Target	By 2011
Sales of alternative-energy vehicles (including mild hybrid and stop-start)	5% of total passenger vehicles
2010 capacity of alternative-energy vehicles	500,000 units

Source: J.D. Power and Associates Research

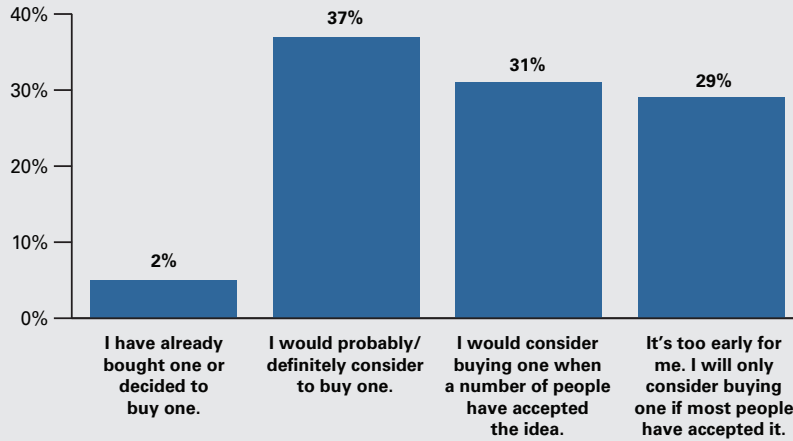
Profile of HEV and BEV Consumers in China

Even though China is the largest vehicle market in the world, vehicle ownership in that country is still in a nascent stage of development. For example, 80% of new-vehicle buyers are first-time buyers, compared with just 10% in the United States. The number of HEVs and BEVs sold in China in 2010 will reach only 10,000 units, and many of these will belong to state-owned enterprises or government agencies. As a result, J.D. Power has been able to develop only a small amount of demographic information to date about personal HEV and BEV buyers in China. Nevertheless, J.D. Power has compiled information about consumer attitudes toward HEVs and BEVs.

- On a positive note, nearly 40% of automotive consumers surveyed in China say they “probably would” or “definitely would” consider purchasing an HEV or BEV.



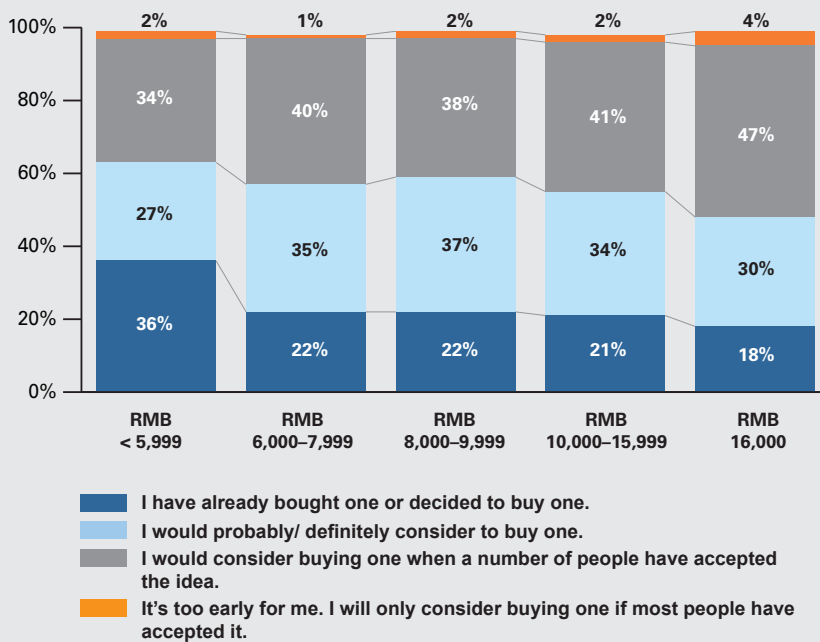
Acceptance of New Energy Vehicles



Source: J.D. Power Netease New Energy Auto Survey

- Research also shows that as income level increases, consumers indicate higher levels of acceptance of HEVs and BEVs.

Acceptance of HEVs and BEVs

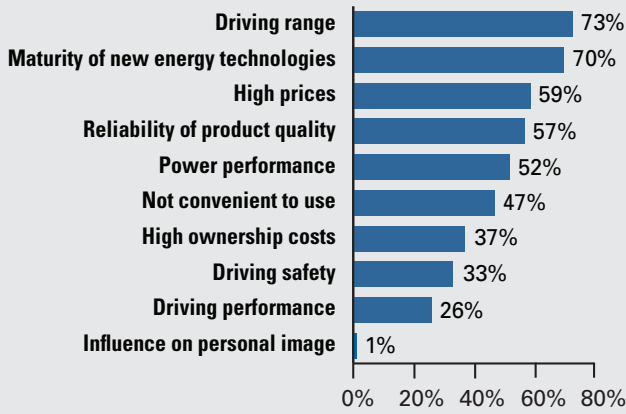


Source: J.D. Power Netease New Energy Auto Survey

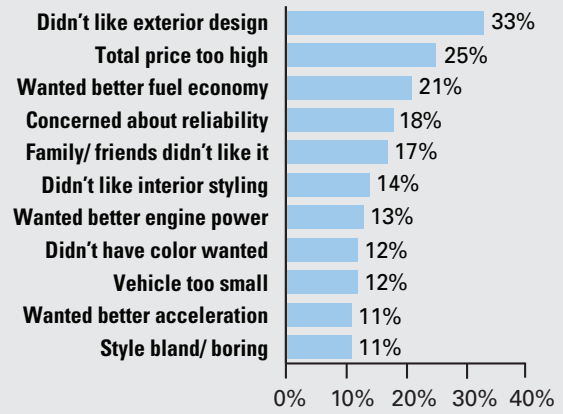
- The major concern for consumers regarding NEVs is not the higher prices of these vehicles—which can be 25%-100% higher than traditional vehicles—but rather the driving range and the reliability of the new technologies. The most important factors to NEV buyers are significantly different from those of buyers of traditional internal combustion engine (ICE) vehicles.



New Energy Vehicle Intenders



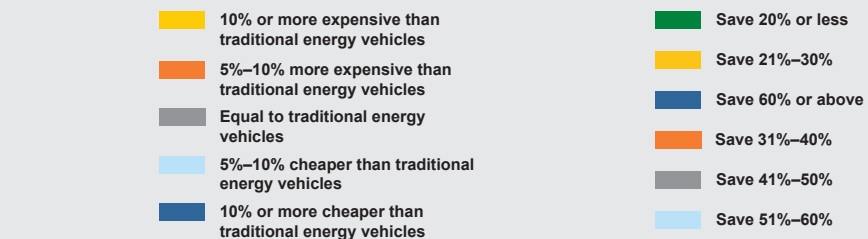
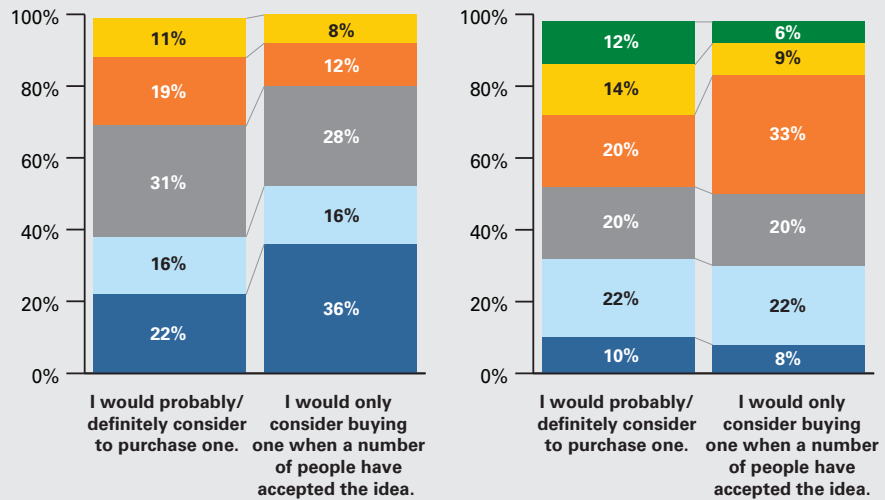
Traditional Energy Vehicle Intenders



Source: J.D. Power Netease New Energy Auto Survey

- While there is interest in NEVs, consumers want them to be available at the same price levels as expected for vehicles with traditional ICEs, or they expect to gain 41%-50% reductions on gas expenditures, which would offset the vehicle price. While it is unlikely that the price of HEVs and BEVs will decline to the price levels of ICE-powered vehicles, reductions in fuel expenditures of 41%-50% are already possible for many HEVs.

Interest in NEVs



Source: J.D. Power Netease New Energy Auto Survey



Conclusion

In addition to addressing the issue of subsidies to keep gasoline prices low and improvements needed to alleviate consumer concerns regarding the dependability of HEV and BEV technology, China must confront other challenges to successfully promote sales of new energy vehicles.

These include:

- The equipment and technology for producing some key battery components (e.g., battery diaphragm) are retained by other countries. Currently, these components can only be imported.
- China's own development of HEV engines has yet to be proven. China's success may rely on its automotive industry's ability to form partnerships with international sources.
- Automakers in China will need to establish common requirements, as there are already disagreements regarding the country's electric-vehicle standard (plug-in vs. removable battery), an indication that there could be more such disagreements in the future.
- China may face increasing global pressure with respect to fair trade practices or limiting international collaboration, as industry experts expect Chinese government incentives for HEVs and BEVs to be provided primarily to domestic manufacturers.

While the above concerns and issues are significant in their own right, unless the Chinese government develops a strategy with detailed plans for the promotion of electric or new energy vehicles, and develops the infrastructure needed to address the issue of driving range, growth in the near to medium term could reach a plateau or even stagnate. That said, of the markets analyzed in this report, China also maintains the greatest ability to enforce conformance to mandated standards and possesses the greatest future potential to promote a coordinated industry plan for HEVs and BEVs.

Non-Battery-Based Technologies

The exact paths for the mass transition to the electrification of modern vehicles—and the timing in which it can be achieved—are subjects of much debate.

Due to the economic and technological hurdles faced by the mass electrification of vehicles—coupled with the skepticism that most vehicle buyers today hold for any technology except the internal combustion engine (ICE)—the ICE will continue to be the dominant technology powering the world's passenger vehicles during the next 5 to 10 years.

Absent government regulatory intervention, such as higher taxes on oil or financial subsidies for automakers or consumers who invest in hybrid or battery electric vehicles, it is likely that petroleum-based fuels will continue to be the principal energy source for the foreseeable future.

Perhaps an even more critical aspect in the transition to the mass electrification of passenger vehicles is the reduction of vehicle exhaust emissions. The potential effect of exhaust emissions on the environment and atmosphere will likely have an even more visible role on the global stage. Today's aggressive regulatory targets for emissions reduction—which is being led by Europe, followed by the United States and Japan—will most likely not be achieved using battery-based technologies alone, given the regional forecasts outlined previously. To that end, governments and industry will look to other means of reducing tailpipe emissions, particularly CO₂, in the short term.

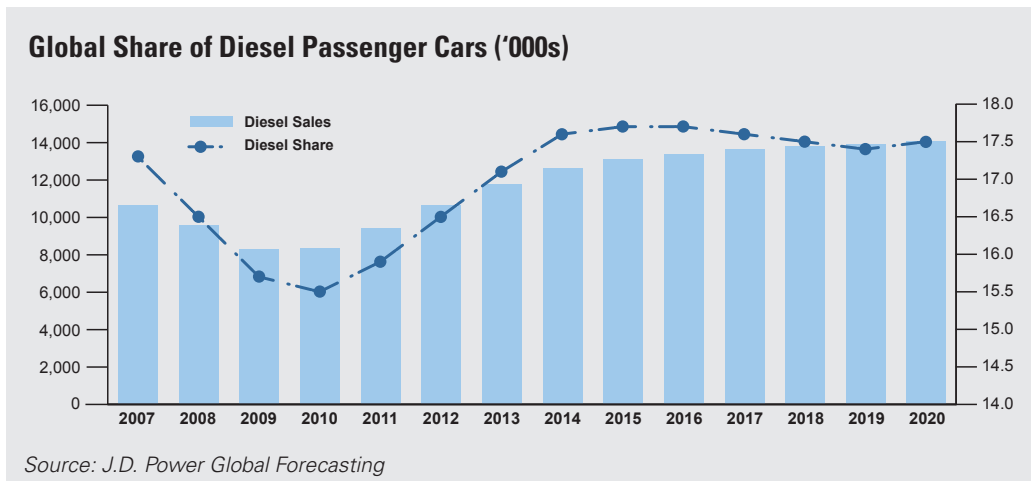
In addition to battery-based options, there are numerous alternatives to the gasoline-powered ICE. These include diesel, biodiesel, natural gas, liquefied propane gas, E85, and fuel cells. Based on J.D. Power research and interviews with automotive industry executives, there are likely three energy sources or technologies that are best positioned for a greater role in future powertrain configurations: diesel, natural gas, and improvements to the ICE.

Diesel

The diesel engine has undergone notable improvements in the past two decades, and as a result offers significant advantages in several areas, compared with the ICE. Diesel engines are more powerful, less complex, typically last longer, have greater low-end power (due to increased torque commonly associated with diesels), and are approximately 30%-35% more fuel efficient than gasoline-powered ICE engines of similar displacement. Their greater fuel efficiency translates directly into lower CO₂ tailpipe emissions, because less fuel is burned to achieve power equal to that produced by a gasoline engine.

Diesel-engine technology does have drawbacks. Diesel engines typically emit higher levels of PM and NO_x, a key contributor to smog. However, regulatory changes in the early 2000s in many of the world's largest automotive regions have led to drastically lower tailpipe emissions in modern diesel engines.

Government-mandated use of ultra-low sulphur diesel, or clean diesel, has allowed vehicle manufacturers to more effectively utilize pollution control devices to reduce PM and NO_x emissions. As a result, many of these vehicles now meet the same emissions standards as gasoline-powered vehicles. Filter traps are used to burn off particulate matter, while NO_x is reduced by either trapping it or periodically changing the engine's air-to-fuel mixture to burn it off, or by adding urea to the exhaust in a second catalytic converter that reduces nearly all of the remaining NO_x and converts it to water vapor and nitrogen.



Consumer perceptions present another challenge. Although diesel engines manufactured today are drastically different than those of the recent past, misconceptions still remain in many automotive markets, particularly the United States. Unpleasant olfactory and auditory recollections of the older diesel engines, coupled with lingering consumer perceptions of them being dirty, still remain. On a positive note, these consumer perceptions are beginning to change.

J.D. Power and Associates projects that diesel share of US passenger-vehicle sales will increase from approximately 0.8% (91,000 units) in 2010 to approximately 5.8% (1.0 million units) by 2020. Diesel sales in Japan will amount to only a few thousand units in 2010, but are forecasted to reach 6.9% (301,000 units) of the Japanese passenger-vehicle market by 2020.

Conversely, as diesels have been much more prevalent in Europe for decades, they should account for a 43% share of passenger-vehicle sales in 2010, but are expected to decline to 35% by 2020 as the European market enacts tougher exhaust emission regulations. By comparison, diesel market share in China is expected to represent less than 1% (74,000 units) in 2010, and to grow modestly to 3.5% (502,000 units) of the market in 2020.

Natural Gas

Natural gas (NG), either in compressed or liquid form, offers a few key advantages, compared with gasoline or diesel. Most notably, tailpipe emissions produce 60%-90% less smog and 30%-40% less greenhouse gases than gasoline or diesel, and NG is less expensive than gasoline or diesel at the pump.

In the United States, NG has another key advantage, as it is plentiful: approximately 85% of NG currently consumed in the United States is produced domestically, while the remaining 15% is imported from Canada. Industry experts believe the supply of NG in North America is more than adequate to be a viable fuel source in passenger vehicles for the foreseeable future. As a result, NG not only offers reduced emissions, but also reduces dependence on imported oil.

There are also some disadvantages of NG as a fuel source, including a lower driving range per tank and, on a global basis, an undeveloped fuel delivery infrastructure. For example, in the United States, there is less than one NG refueling station for every 100 gasoline stations.

Since NG cannot be transported to stations and delivered to consumers from the existing gasoline and diesel infrastructure, the cost and time involved to develop a new NG distribution system would likely be substantial. While creating a global or national NG distribution system presents a challenge, successfully addressing this challenge now could deliver benefits in the long term, because NG stations may be easily converted to also deliver hydrogen in the future. Many industry experts believe that fuel cells—powered by cheap, plentiful, and clean hydrogen—are the long-term solution for powering passenger vehicles of the future.

ICE Improvements

As discussed previously, not only does J.D. Power and Associates expect that the gasoline-based ICE will maintain its market dominance through 2020, but also that the technology will most likely remain the most prevalent automotive technology for many years following that.

In recent years, significant improvements to the ICE have been developed and delivered to the marketplace, as OEMs across the globe attempt to meet increasingly stringent fuel-efficiency and tailpipe-emissions requirements. According to industry experts, some key ICE improvements and the estimated increase in fuel economy and reduction in exhaust emissions they provide include:

- **Variable Valve Timing and Lift**—Traditionally, engine valves have utilized a fixed timing and lift to control the flow of air and fuel to the cylinder. However, electronically alternating when valves open and for how long (for optimal performance) could increase fuel economy and reduce exhaust emissions by up to 5%.
- **Cylinder Deactivation**—Engineering advances now allow engines to electronically deactivate cylinders when not needed. For example, a vehicle powered by a six-cylinder engine and cruising at highway speeds could be made to run on only four cylinders, thus reducing fuel consumption and emissions. If more speed is required for passing, the engine could electronically engage the two dormant cylinders for more power. Depending on how the vehicle is used, fuel economy could be increased and exhaust emissions decreased by up to 7.5% each.

- **Turbochargers**—Turbochargers, which use ultra-high-speed fans to force more air into the engine's cylinders for maximum power, have long been associated with high-performance vehicles. When calibrated for optimal fuel savings, the extra power a turbocharger provides may also mean a reduction in engine size, resulting in increased fuel economy and decreased exhaust emissions by up to 7.5% each.
- **Stop-Start Technology**—Stop-start technology is currently used extensively in hybrid vehicles, and is expected to be widely introduced into ICE configurations in the coming years. Stop-start technology involves an electronic system that turns the engine off when the vehicle is idle, and restarts the engine instantly once the throttle is re-engaged. Stop-start technology is typically coupled with regenerative braking, and the electricity generated when braking is stored to power the automatic starter. If a vehicle is frequently driven in heavily congested areas that require numerous stops, it is estimated that stop-start technology may increase fuel economy and decrease exhaust emissions by up to 8% each.

J.D. Power predicts that ICE improvements and diesel will play major roles in the near future. Natural gas offers a great deal of potential, but the biggest challenge is the refueling infrastructure it requires. Regardless, as the world moves toward more battery-based technologies to power vehicles, these non-battery-based technologies will assist significantly in the greening of the global automotive industry.

Conclusion

It is evident that leaders of the world's largest industrial nations are more committed than ever to the reduction of exhaust emissions and greenhouse gases. It is also evident that any migration to environmentally friendly passenger vehicles in the future can only be achieved if the green business model is made economically sustainable, and is not dependent on government subsidies or credits.

The challenges of transforming the global automotive fleet from petroleum-based technology to battery-based technologies remain numerous. These challenges include economic and technological hurdles; logistical complications with power delivery; and consumer-resistance issues based on vehicle performance and expense. Importantly, it should be noted that these are the same types of problems that inventors and entrepreneurs faced more than 100 years ago at the dawn of the automotive age.

Given these challenges, sales of HEVs and BEVs are expected to account for only slightly more than 2.2% of global passenger-vehicle sales in 2010, and only 7.3% of global passenger-vehicle sales in 2020.

The appeal of HEVs, BEVs, PHEVs, and ER-EVs is that tailpipe emissions are reduced drastically or completely, and these technologies decrease reliance on the use of oil. The drawback is that fossil fuels are still often used to produce the electricity that powers these vehicles. As a result, it is not clear whether there is a substantial reduction in emissions by switching completely to these technologies. In addition, the battery packs for such vehicles are prohibitively expensive to manufacture on a large scale, and disposing of depleted battery packs presents another environmental challenge.

Rather than rushing to commercialize BEVs, the industry might be better served to pursue continued fuel economy improvements in ICEs and the mass production of HEVs. HEVs have many benefits: they are a proven technology and have high consumer awareness; cost substantially less to produce than BEVs; have excellent driving range, very low exhaust emissions, and offer excellent fuel economy; and require no new infrastructure to support them.

As the world advances toward electric vehicles in the future, it must also be recognized that the gasoline ICE will continue to play a central role, especially during the next 10-15 years. Therefore, in order to safeguard the environment today, it will remain important to pursue continuous improvements in ICEs and allow time to map out the future.

Table of Global HEV/BEV Sales (2007-2020)

HEV/PHEV												
GLOBAL	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
HEV/PHEV	515,397	515,135	728,215	934,644	1,237,167	1,715,812	2,102,503	2,454,493	2,781,643	3,138,050	3,402,227	3,883,447
Total PV Sales	48,989,462	45,808,919	43,865,494	44,708,783	47,621,688	52,305,128	55,623,828	58,661,294	61,198,064	63,250,564	65,145,316	70,905,762
HEV/PHEV %	1.1%	1.1%	1.7%	2.1%	2.6%	3.3%	3.8%	4.2%	4.5%	5.0%	5.2%	5.5%
US	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
HEV/PHEV	353,152	316,251	291,659	291,116	482,675	801,852	1,051,154	1,287,087	1,466,070	1,583,161	1,586,435	1,672,739
Total PV Sales	16,288,029	13,408,290	10,570,294	11,868,597	13,955,528	15,318,387	16,086,657	16,478,416	16,611,600	16,823,614	16,996,861	17,426,043
HEV/PHEV %	2.2%	2.4%	2.8%	2.5%	3.7%	5.3%	6.7%	7.9%	8.9%	9.5%	9.4%	9.6%
China	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
HEV/PHEV	414	899	1,883	3,781	16,603	31,286	41,285	52,078	64,674	78,387	81,968	97,234
Total PV Sales	5,438,818	5,934,448	8,721,280	8,164,591	9,071,331	11,050,314	12,161,671	13,250,510	14,281,779	15,070,676	15,775,472	17,461,796
HEV/PHEV %	0.01%	0.02%	0.02%	0.05%	0.2%	0.3%	0.3%	0.4%	0.5%	0.5%	0.5%	0.6%
Japan	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
HEV/PHEV	96,498	120,725	348,410	475,872	470,021	562,870	603,239	617,359	648,079	723,931	748,757	874,984
Total PV Sales	4,338,106	4,203,238	3,901,957	4,343,645	4,199,118	4,245,434	4,244,883	4,230,317	4,217,242	4,201,986	4,183,772	4,194,000
HEV/PHEV %	2.2%	2.9%	8.9%	11.0%	11.2%	13.3%	14.2%	14.6%	15.4%	17.2%	17.9%	20.9%
Europe	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
HEV/PHEV	64,900	76,217	73,818	108,241	165,757	213,789	271,434	361,057	455,705	605,538	789,880	977,806
Total PV Sales	19,402,402	18,519,287	16,512,240	15,630,067	15,593,200	16,437,820	17,532,581	18,780,021	19,839,094	20,594,727	21,285,220	23,815,684
HEV/PHEV %	0.3%	0.4%	0.4%	0.7%	1.1%	1.3%	1.5%	1.9%	2.3%	2.9%	3.7%	4.1%
BEV												
GLOBAL	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
BEV	436	1,132	3,517	20,150	89,891	221,815	383,679	530,000	639,822	796,700	943,725	1,311,441
Total PV Sales	48,989,462	45,808,919	43,865,494	44,708,783	47,621,688	52,305,128	55,623,828	58,661,294	61,198,064	63,250,564	65,145,316	70,905,762
BEV %	0.00%	0.00%	0.01%	0.05%	0.19%	0.42%	0.69%	0.90%	1.05%	1.26%	1.45%	1.85%
US	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
BEV	0	151	1,310	2,002	13,792	41,566	70,440	85,946	88,414	90,792	97,016	107,998
Total PV Sales	16,288,029	13,408,290	10,570,294	11,868,597	13,955,528	15,318,387	16,086,657	16,478,416	16,611,600	16,823,614	16,996,861	17,426,043
BEV %	0.0%	0.001%	0.01%	0.02%	0.1%	0.3%	0.4%	0.5%	0.5%	0.5%	0.6%	0.6%
China	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
BEV	-	-	-	5,116	17,032	35,070	60,384	90,473	129,591	189,055	217,320	332,775
Total PV Sales	5,438,818	5,934,448	8,721,280	8,164,591	9,071,331	11,050,314	12,161,671	13,250,510	14,281,779	15,070,676	15,775,472	17,461,796
BEV %	0%	0%	0%	0.1%	0.2%	0.3%	0.5%	0.7%	0.9%	1.3%	1.4%	1.9%
Japan	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
BEV	-	-	986	8,282	17,703	30,497	38,398	43,777	47,444	50,290	52,142	67,057
Total PV Sales	4,338,106	4,203,238	3,901,957	4,343,645	4,199,118	4,245,434	4,244,883	4,230,317	4,217,242	4,201,986	4,183,772	4,194,000
BEV %	0%	0%	0.03%	0.2%	0.4%	0.7%	0.9%	1.0%	1.1%	1.2%	1.2%	1.6%
Europe	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2020
BEV	436	471	338	3,221	38,362	99,824	190,629	269,953	337,892	423,920	530,013	742,020
Total PV Sales	19,402,402	18,519,287	16,512,240	15,630,067	15,593,200	16,437,820	17,532,581	18,780,021	19,839,094	20,594,727	21,285,220	23,815,684
BEV %	0.002%	0.003%	0.002%	0.02%	0.2%	0.6%	1.1%	1.4%	1.7%	2.1%	2.5%	3.1%

Acknowledgements

J.D. Power and Associates would like to acknowledge and thank the following for sharing their time and insights during the development of this report:

John Hanson	National Manager, Environmental Safety and Quality Communications Toyota Motor Sales U.S.A., Inc.
Robert Bienenfeld	Senior Manager, Environment and Energy Strategy American Honda Motor Co., Inc.
Shai Agassi	Founder and CEO, Better Place
Andrew J. Littlefair	President and CEO, Clean Energy Fuels Corp.
Ed Begley Jr.	Actor and Environmentalist

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J.D. Power and Associates 2010 U.S. Initial Quality StudySM (IQS)

J.D. Power Asia Pacific 2009 Japan Sales Satisfaction (SSI) Index StudySM

J.D. Power and Associates 2010 Germany Vehicle Ownership Satisfaction StudySM (VOSS)

J.D. Power and Associates 2010 France Vehicle Ownership Satisfaction StudySM (VOSS)

J.D. Power and Associates 2010 UK Vehicle Ownership Satisfaction StudySM (VOSS)

J.D. Power Netease New Energy Auto Survey (China)

International Energy Agency (IEA)

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Jeff Schuster is Executive Director of Global Forecasting and Product Analysis at J.D. Power and Associates. He is responsible for the entire automotive intelligence and global forecasting operation, directing activities for North America, South America, Europe, and Asia Pacific. He leads current assessment and future outlook of vehicle sales, vehicle production, and powertrain applications across the automotive industry. In addition, he directs the group's global product analysis function, including future vehicle activity, competitive trends, and segmentation shifts. Mr. Schuster has been tracking developments in the automotive industry for more than 15 years. He is one of J.D. Power's primary automotive industry experts and is widely quoted by the media on a global scale—including print, radio, and television. He also makes numerous industry presentations on topics such as regional or country-level outlooks, segmentation trends, and OEM analysis and strategies and presents at many of the company's Roundtables and seminars. Prior to joining the company in 1996, Mr. Schuster was a treasury analyst for Lear Corporation. He was responsible for cash management of the Canadian operation and was active in merger and acquisition activity.



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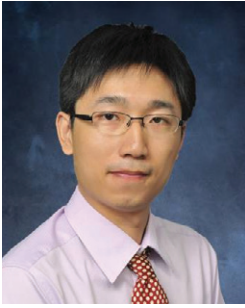
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Marvin Zhu is a Senior Market Analyst for China operations in the Shanghai office of J.D. Power Asia Pacific. He specializes in analyzing and forecasting the automotive industry in China and Taiwan, and provides clients with analyses on the structure of the industry, government policy, current development and insights into future trends.

Mr. Zhu has an extensive background in automotive engineering. Before joining J.D. Power Asia Pacific in 2008, he worked for three years at Delphi Chassis as a manufacturing engineer. There, he was responsible for the brake products production lines for two years, during which time he led the launch, debug and continuous improvement of several vehicle programs, including Buick LaCrosse, Excelle, Epica, GL8, Cadillac SLS and Chery B11/B21. He was also an application engineer at the company's technical center, which provides customer support.

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