Flipping the switch to electric cars: Seven factors transforming the future of the automotive industry

# The e-mobility era: Winning the race for electric cars

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# Flipping the switch to electric cars: Seven factors transforming the future of the automotive industry

By the year 2020, one in two new cars will be either partly or fully powered by electricity. That may surprise many market observers, who regard the current hype and numerous battery-powered prototypes as a knee-jerk reaction by an automotive industry under stress. But e-mobility is no marketing fancy. Bain & Company presents seven reasons that explain why an industry switch to electric cars in their various forms constitutes a fundamental and irreversible change:

1. In 10 years, at the latest, the e-car will be a mass-market product
2. E-cars are being launched as today's new lifestyle product
3. The electric car is not just a product variant—it represents a fundamental system change
4. E-cars do not need an expensive infrastructure to succeed
5. The available e-car technology today is already "good enough"
6. Battery costs will be at a mass-production level by 2015
7. The electrification of the automobile is compelling and inevitable.

## There is no alternative to the e-car

In July 2006, the newly established auto company Tesla presented an exclusively electric-powered sports car at a sticker price of more than $100,000. A host of celebrities ordered one on the spot, and suddenly e-cars were hot. Within a few years, what had been a sideline became an image platform on which the industry's hopes for the future rested. Though virtually none of the carmakers had an e-car to offer for daily use, from that point on, the media landscape, the political scene and the motor shows were dominated by battery-powered vehicles.

Since then, every major car manufacturer has joined the e-mobility bandwagon. German premium automakers were quick off the mark: The past year has seen a crop of pilot and concept cars, with two e-Tron prototypes from Audi, the E-Mini and the ActiveE from BMW, and the Smart Electric Drive (ED) and BlueZERO from Mercedes-Benz. Japanese companies like Toyota and Honda and US companies such as General Motors and Ford are in the fray, along with Chinese brands like BYD, Cheery and Geely. By 2012, there will be more than 100 partial or fully electric vehicle brands in the market.

But when and how will the e-car genuinely become a mass-market product? What justification is there—economically as well as ecologically—for consumers to turn to electric vehicles? And how quickly will these vehicles catch on? In this report, Bain & Company looks at the market opportunities, the ecological case for the e-car, the economic feasibility of electrification and the challenges facing the automotive industry today.

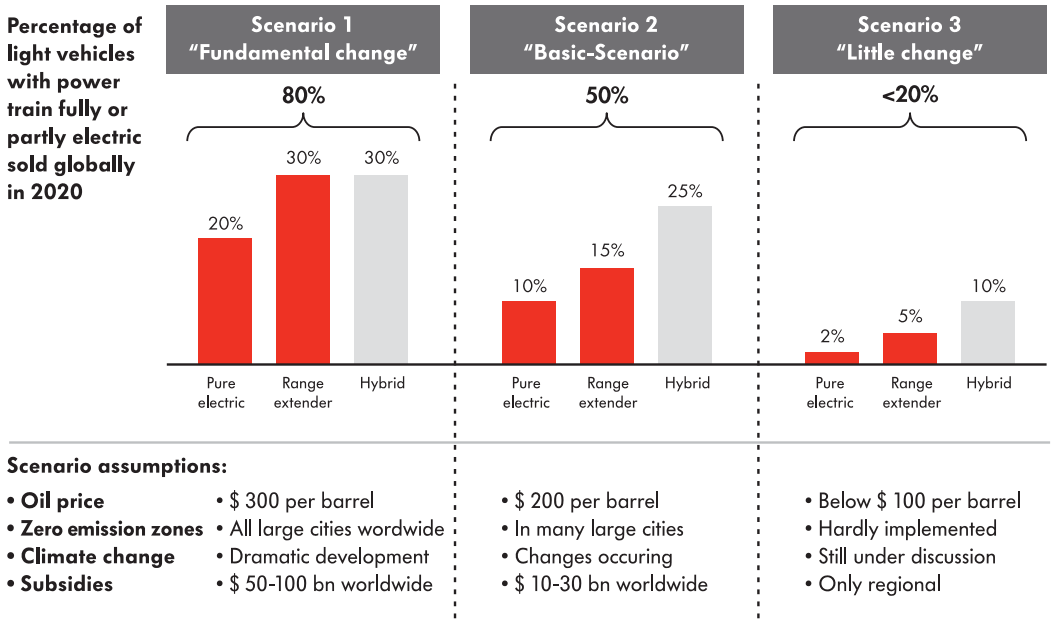
### 1. In 10 years, at the latest, the e-car will be a mass-market product

A recent worldwide study by Bain & Company demonstrates that customers genuinely want e-cars. They are excited by the image, the tech-

nology, the environmental advantages and—for those who have already been able to drive one—the sheer driving experience. In addition to this customer-led "pull," the trend toward e-mobility is also accelerated by numerous and sustainable "push" factors. First among them is cost. The more battery prices fall to a level of economic viability while fuel prices rise, the more economical e-cars become compared with conventional vehicles. Second, consumers and governments in densely populated urban areas eagerly await e-cars as a means to reduce their local emissions. Third, national governments are trying to meet their climate protection targets and at the same time promote homegrown industry. Finally, car manufacturers must dramatically reduce the [$CO_2$ levels their cars emit and, sooner or later, will put their design emphasis on vehicles with electric propulsion. These four factors will create huge growth potential for electrification technology before the end of this decade—and they present a unique opportunity for the auto industry.

In this scenario, we estimate that, by the year 2020, half of all new cars registered worldwide will have an electric drivetrain, even if the majority are also likely to be fitted with a combustion engine—either as a backup "range extender" or as a full or plug-in hybrid (see Figure 1). And 10 percent of all new cars in 2020 will be entirely battery-powered e-cars, pure and simple. These cars will primarily be used for daily driving and commuting, and drivers will be accustomed to their limitations. For longer trips, consumers will either use another vehicle with greater range or turn to car-sharing or public transportation. Again, costs will be a

Figure 1: By 2020 the electric drivetrain will prevail worldwide



major factor. Not only will e-cars offer a good environmental image, but by 2020 they will be no more expensive than conventional vehicles—in fact, their overall cost of ownership will be far cheaper.

What about those consumers who cannot manage with the current range of purely battery-powered cars that run 100 to 150 kilometers (about 60 to 90 miles) on a full charge? Or those who cannot afford a second car? Even for those traveling longer distances in and from the suburbs, there is still no need to forgo e-mobility. Their option will be to use a car with a smaller battery and an additional combustion engine as an emergency power plant. In that way, most driving can still be done in electric mode—which will soon be an essential requirement to enter the environmentally restricted zones that many cities are planning to create. Indeed, in the inner core, cities will offer concessions for e-cars—such as free parking, use of taxi lanes or exemption from urban-center tolls—if they do not restrict entry to emission-free vehicles altogether.

### 2. E-cars are being launched as today's new lifestyle product

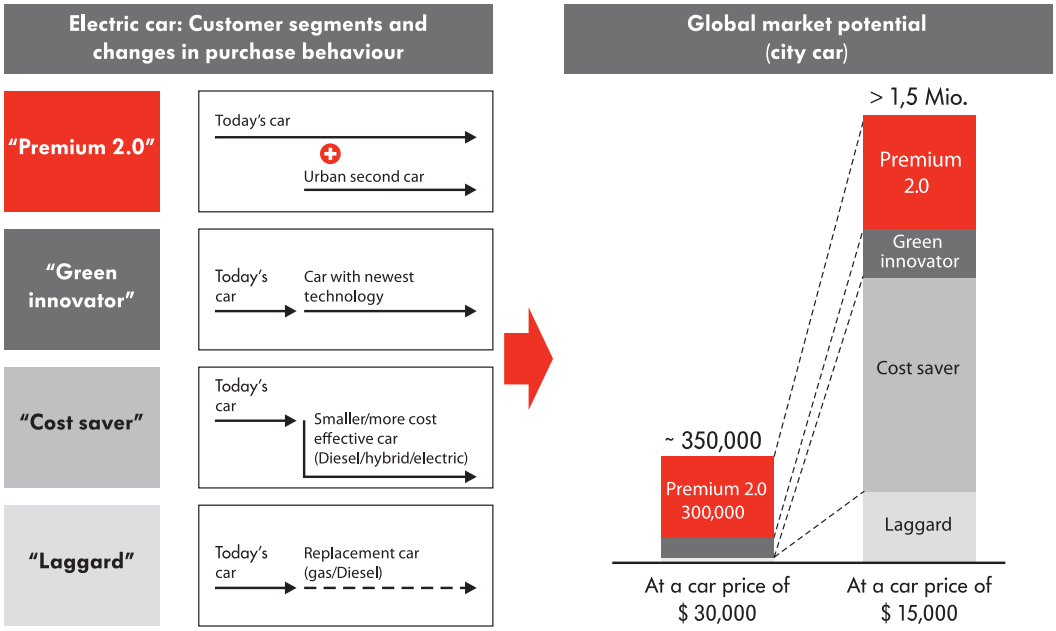
An extensive global market survey by Bain in 2008 and 2009 identified an annual potential of 350,000 e-car customers worldwide, including 100,000 in Europe alone. Those surveyed said they would buy an electric car even at twice the price of the comparative conventional city car, used as a baseline in the survey. These customers are predominantly high-earning, environmentally aware city dwellers who already own a premium vehicle. They said they would use the e-car mainly as a second or third car, mostly for short trips. This group of customers, which we call the "Premium 2.0" segment, is not price sensitive in that by buying an environmentally friendly e-car they can be seen to be green (see Figure 2).

The example of the Tesla Roadster shows that these early adopters are also motivated by an enthusiasm for technology and by the desire to stand out—the same buying criteria that apply to other innovative high-tech products. The e-car brings an added awareness that their drivers are doing something good for the environment. What's more, this group feels a need to pioneer ecological trends, and to be seen as doing so.

To date, only a few people worldwide have driven the various e-cars that have been built as prototypes or in small lots. BMW, for example, is conducting field trials in Berlin and Los Angeles with 600 E-Mini prototypes. Daimler has 100 Smart Electric Drive cars on the streets of London and has just started another field trial with 1,000 new-generation vehicles in various major cities. Tesla customers are testing some 1,000 cars—including 150 in Europe, and the feedback from drivers, after a brief period of familiarization, is positive. Their verdict: "We want to buy these cars. They are already technically good enough; they're fun to drive and environmentally friendly."

Drivers' new feelings of satisfaction have little to do with conventional premium attributes, such as luxury, size or power. On the contrary, with an e-car, the Premium 2.0 consumers want to express a new attitude. Their motives for doing so vary: Some are eager to be seen as technological pioneers; others want to get away from conventional models that are more and more alike; still others see the e-car as a political statement. One telling comment from a US driver was: "We want to make our country

Figure 2: The market for electric cars is taking off now in the "Premium 2.0" customer segment




more independent from oil." Broadly speaking, this growing customer segment is trying to live a more ecologically sound life. With such undercurrents, the e-car provides a personal-values platform for a new lifestyle that combines ecological awareness with individual mobility in urban centers.

The Chevrolet Volt, slated to launch later this year, shows how stylish e-cars can stimulate enthusiasm. The Volt will be powered exclusively by an electric drive that will primarily draw power from a battery charged by an electric outlet. However, the car will also have a small combustion engine that can generate power for longer trips. This e-car concept is called a range extender. Thousands of potential customers in the United States are eagerly awaiting the vehicle's launch. They are even discussing on Internet forums how to optimize their daily routes so that the car can be driven exclusively in e-mode. E-car communities are springing up, and the media is stoking patriotic feelings by exhorting people to "buy American high-tech." The Volt has everything it takes to be a market success—not the least of which is the $7,500 tax incentive the US government is offering every buyer. So beyond its "curb appeal," the car is also an attractive cost proposition, even given the current comparatively lower gas prices in the United States.

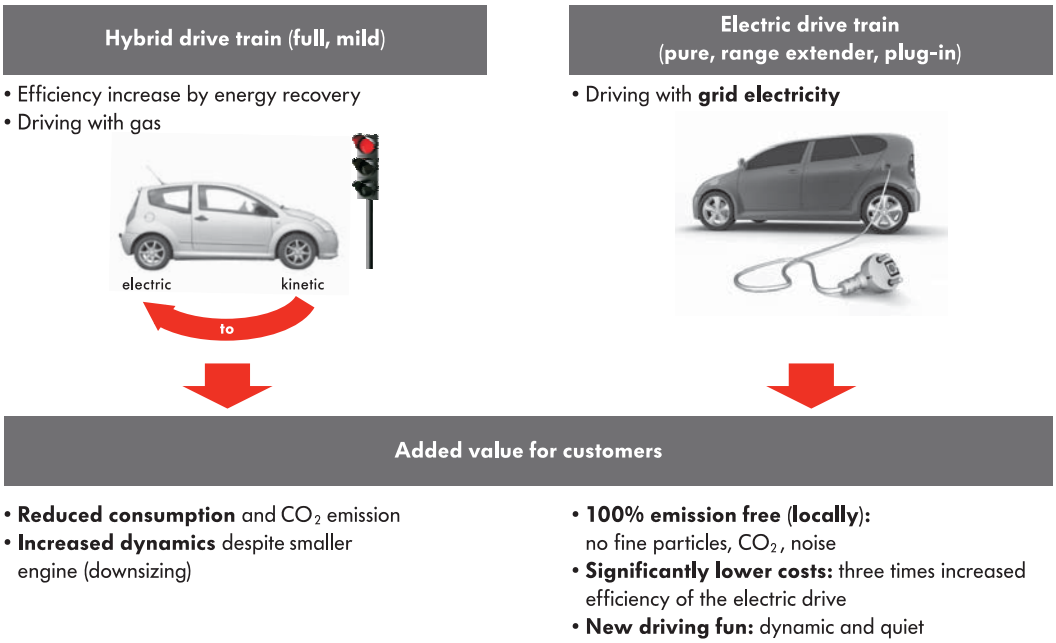
### 3. The electric car is not just a product variant—it represents a fundamental system change

The electric car will be the automotive industry's equivalent to the iPhone. When Apple presented its new product to the world in 2007,

cell phone manufacturers scoffed.The iPhone did not have a removable battery and required recharging almost daily because of its high power consumption. In contrast, one could use another manufacturer's phone for a week without having to recharge it. Despite these apparent drawbacks, to date more than 35 million people worldwide have bought an iPhone. The fact is, the iPhone is not a new mobile phone, but an entirely new product that allows its customers to enter a previously unimaginable world of applications, turning one of the previous paradigms of the telecommunications industry on its head. The electric car has the same kind of potential.

Customers who buy an e-car are not just buying a new car. They are changing to a new system (see Figure 3). Suddenly, the car no longer uses gasoline, it uses electricity. The ride is whisper-silent but dynamic beyond accustomed standards. There are no flat spots or jerky gear changes, and the car is extremely nimble in the city. It also produces no local hazardous emissions, with a corresponding positive effect on the user's personal $CO_2$ balance. The related infrastructure problems now shift to the power generators. But with today's energy mix in Europe, e-cars such as the Smart Electric Drive have a $CO_2$ output of just 75 g/km. Drivers will also benefit—immediately, and for the entire life of the vehicle—from lower carbon emissions from the power station network and from the move toward greater use of renewable energy for power generation. That also represents a genuine paradigm shift.

Figure 3: E-car customers "change the system" and gain substantial extra benefits



For many emotional reasons, rationally supported arguments and data comparing the combustion engine and the electric drive will fail. When a systemic change takes place, customers no longer perceive product attributes they have come to expect in the past (such as an 800-kilometer or nearly 500-mile range on a tank of fuel, for instance) as quite so important anymore. Customers want the new product because it offers new opportunities. Customers switched to the iPhone-like system because of the new apps, not because of how long the battery lasted on standby.

Some governments have already gotten the message that the development of the electric car heralds a systemic change. Both China and the United States have adopted policy positions that their domestic auto industries must be supported in the development of electric vehicles and that e-car sales must be significantly subsidized with tax dollars. In both countries, this policy shift is also being hastened by the realization that global competition is overpowering their domestic auto manufacturers. Consequently, they are seizing the e-car opportunity and substantially investing in new technologies. The declared aim is to develop mass-produced e-cars and bring them to market as rapidly as possible. In Europe, France is alone in adopting a clear stance in support of its domestic auto industry. Every French customer will receive a $6,000 government subsidy per French car, and the manufacturers PSA and Renault are receiving generous funding.

Are such subsidies justified in industrial policy terms? History says yes, as governments have played a role in the introduction of every significant new, transformational technology. For example, today's individual mobility is only possible because governments have made considerable investments in roads and infrastructures. The global telephone and data network, too, would not exist were it not for major funding from the public coffers. The huge investment in the first transatlantic cable could certainly not have been paid for by the few international telephone customers of the day.

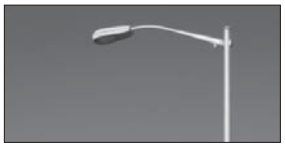
Based on that historical basis, there would be little justification in leaving the first buyers of e-cars to finance the still very high cost of batteries on their own. Only when sufficient numbers of batteries are made and sold will the production costs fall, allowing the development cost to be amortized across large volumes.

Practically speaking, of course, people no longer question if e-cars will be subsidized, but merely where and to what extent. The coming systemic change will arrive sooner in regions with high e-car subsidies, and their local industry will have a head start. So this sea change in technology will also be a contest among regions.

## 4. E-cars do not need an expensive infrastructure to succeed

The debate on e-mobility frequently revolves around infrastructure: public recharging stations, plug standardization and systems for swapping rechargeable batteries. However, Bain's analyses show that the success of e-mobility is not dependent on the development of a costly public backbone for the switch to any large extent. Most potential customers simply do not need anything new; they would use their own electric outlet or one provided by their employer. The standard charging process is accomplished using domestic electric power via a 110- or 220-volt outlet, with between six to eight hours required for charging (see Figure 4).

Figure 4: The electric car does not need an expensive infrastructure

| User profile | Independents | Office chargers | Street parkers |
|---|---|---|---|
| |  |  |  |
| **Characer-teristics** | • Customers with existing garage or parking space for electric car, (50 - 60 percent) e.g.:<br>- House owners<br>- Flat with garage<br>- Craftsmen (workshop)<br>• Battery charging at home | • Commercial users/fleet customers with a larger number of cars and parking spaces (40 - 70 percent)<br>• Battery charging onsite at company charging station | • Customers without garage or parking space for electric car, (10 - 15 percent) e.g.:<br>- Flat without dedicated parking<br>- Small business without own parking<br>• Battery charging only at public charging station |
| **Demand for public charging infrastrcuture** | Low | Medium | High |

Bain surveyed consumers, who were asked about their personal charging options for a future electric car, and three typical user profiles emerged:

### Type 1: "The independents"

Some 50 percent to 80 percent of e-car users have their own garage or a parking space close to their home (in the United States, the proportion is 80 percent to 100 percent). When finished driving for the day, these users would connect their e-car to a normal electrical outlet. The time needed for a full charge overnight is more than enough for their daily energy needs. All that is required is to equip the parking space or garage with a standard electrical outlet. Around 50 percent of interviewees already had one. The investment needed would be minimal, and the customer would expect to pay for it. Some e-car manufacturers are likely to offer special charging services and products (so-called wall boxes, including an electricity supply contract) for these "independents." Automakers would sell the wall box under their own brand, coincidentally providing an opportunity for an electricity supply partner to acquire new retail customers.

### Type 2: "The office chargers"

Approximately 40 percent to 70 percent of all drivers use a company parking space. Many employers could provide staff with charging facilities at the office. For example, Google has already installed company parking spaces with solar-powered charging facilities at many of its locations. Here too, the eight-hour workday

is enough to charge an electric car with more than enough energy for daily needs. For companies the investment cost is manageable and can be partially integrated into an already existing infrastructure (lighting, for example) and billed at simple flat rates with no need for costly meters. A new law in France actually requires new office buildings to have such infrastructure.

**Type 3: "The street parkers"**

Just 15 percent of drivers have no opportunity to charge an e-car either at home or at work. This relatively small group is the only one currently excluded from using an electric car, at least until public charging facilities become available. The development of public charging stations (for example, using ordinary on-street parking spaces) or charging stations available for public use (for example, in parking garages or shopping malls) will be dependent on political will rather than actual demand. Again, most e-car users would not be reliant on such new infrastructure. What's more, electric charging stations with integrated, intelligent billing technology would be expensive and viable only as a marketing tool, if at all.

In the midterm, the standard electrical outlet will remain the norm in most cases. For "emergencies," quick-charging stations will likely develop. That is, in fact, an emerging business opportunity for gas stations. With a relatively low-cost modification to the current infrastructure they already have, they could allow customers to top off with an 80 percent charge in just 15 to 20 minutes. During this time, the gas station could provide coffee and convenience shopping—a win-win situation.

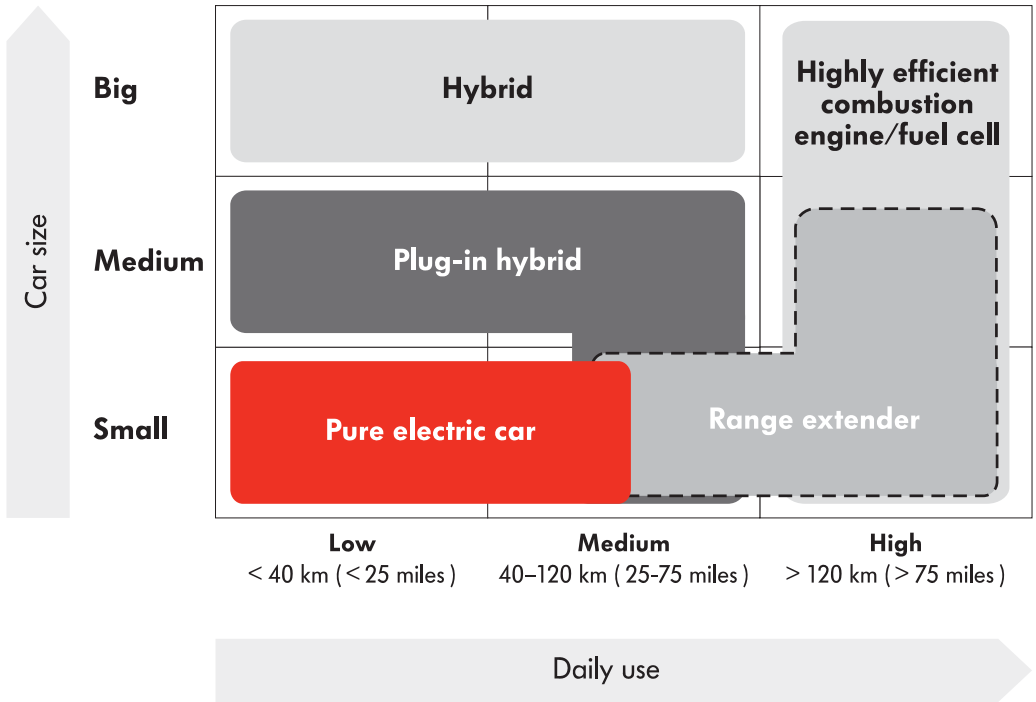
To supply such a fleet of e-cars, most experts do not see the need to build new power plants or massively invest in the existing electricity grid. Even if e-cars accounted for 20 percent of the vehicles on the road, power consumption would rise by only around 4 percent. E-cars would also be charged predominantly overnight when the generators have unused capacity. Nevertheless, demand from suburbs with a high e-car penetration would probably require some investments in higher-transformer station capacity or intelligent demand control in peak periods. Yet, with more future electric power being generated decentrally—solar panels on house roofs, for example—these costs should be limited.

### 5. The available e-car technology today is already "good enough"

One issue for the immediate acceptance of the e-car is whether it is already "good enough" for consumers. Two aspects of e-car technology might argue against this idea: The batteries required make e-cars as much as 50 percent more expensive than conventional cars today, and their range is limited to around 150 kilometers (93 miles) on a full charge. The extra-cost issue may not be as daunting as it seems. It is ultimately a matter of the economies of scale in battery production and of government subsidies, topics discussed in more detail later. However, the range required of a battery is solely a matter of customer acceptance.

The field trials of the Smart Electric Drive and the E-Mini are being accompanied by extensive market research. In both cases, customer surveys show that the drivers were predominantly satisfied with the cars. Indeed, for a substantial majority of the users, these e-cars—despite their so-called handicaps—are already good enough for day-to-day mobility needs (see Figure 5). Likewise, in numerous projects and studies, Bain determined that an attractive

Figure 5: Pure electric cars are for the city and daily needs




market exists both for e-cars charged exclusively via an electrical outlet as well as for vehicles with an auxiliary combustion engine. Let's look at each type of e-car:

**Market opportunity #1: "Battery only"**

E-cars powered solely by batteries for daily commuting, bought by users mainly as a second car, are definitely a competitive prospect. Today in Germany, there are around 10 million second cars. Research by the German Federal Ministry of Transport has shown that Germans travel an average of 37 kilometers (almost 23 miles) per day, 61 percent of which is by car. In the United States, the distance is around 60 kilometers (37 miles), with cars accounting for 86 percent of this distance. For electric cars, that means 80 percent of drivers can park their e-car at home to recharge in the evening with well over half the battery charge still remaining. For vacations and special trips that exceed the battery range, drivers of purely battery-powered e-cars either will use their conventional car or rent a vehicle.

**Market opportunity #2: "Battery plus"**

For drivers unwilling to forgo the range of a gasoline-powered car, plug-in hybrids are ideal. They can be used predominantly for city driving (such as the Toyota Plug-in Prius announced for 2014), or as range-extender hybrids (for example, the Chevrolet Volt). Operated in electric mode for daily driving in the city (20 to 60 kilometers or 12 to 37 miles), they can also be used like conventional cars (with a range of more than 600 kilometers or 370 miles).

Lower-priced batteries that are substantially smaller than those used in pure e-cars compensate for the costs of the dual drives.

Here is an opening for the auto industry's capacity to innovate—a traditional strength. Indeed, the large number of innovations embodied in the range-extender concept for the Chevrolet Volt is remarkable. In combination with an intelligent control system, it provides an entirely new driving experience—one that's on a par with an eight-cylinder engine but with the gas consumption of a three cylinder.

## 6. Battery costs will be at a mass-production level by 2015

To convert a Smart car into an electric car, the production costs of the necessary 16 kWh lithium-ion battery—which supports a range of about 130 kilometers (80 miles)—would currently fall between $8,000 and $10,000. Some 75 percent of that price would be the result of small-scale production using largely manual processes. The raw materials would account for only 25 percent of the costs. In all other respects, an e-car is about as expensive to build as a conventional car with a combustion engine. The electric drivetrain roughly equates to the cost of the traditional components such as the engine, transmission, fuel tank and exhaust.

The battery is the central economic impediment to the widespread rollout of the e-car today. But what would a battery cost if production were running at 100,000 units per year? Or, to put it another way: When will batteries for electric cars be affordable? In an extensive process of reverse-engineering and by applying benchmark analyses, Bain made some calculations based on comparable industrial cost curves.

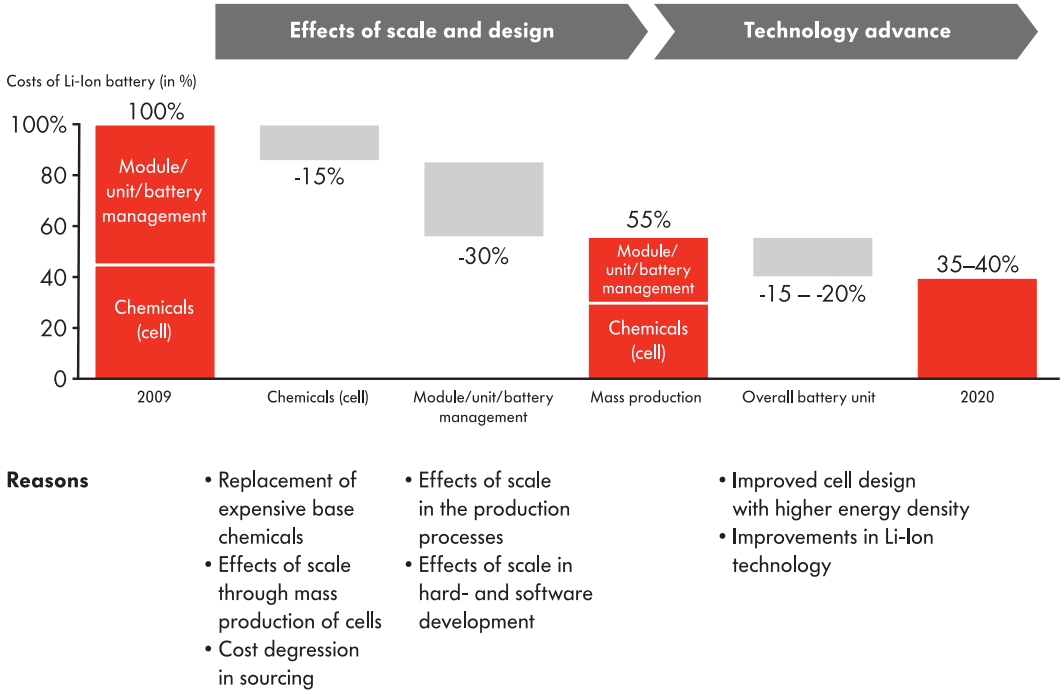
On the basis of those calculations, it appears that from 2015 and beyond, batteries will be available that can make the electric car a viable mass-market product. Bain expects to see manufacturing costs of $250 to $350 per kWh by 2015, and $150 to $250 per kWh by 2020 (see Figure 6). Besides the necessary automation of processes and assembly, this also assumes that other, lower-cost basic chemicals and simplified testing and inspection procedures will be introduced. Given the number of engineering hours and the amount of research funding currently devoted to that technology worldwide, the scenario appears entirely achievable.

By 2015, the battery for a Smart Electric Drive or a Chevrolet Volt is likely to cost only around $4,000; the battery for a Toyota Plug-in Prius, just $2,500. Assuming the battery will have a residual value of $800 to $1,200 at the end of its lifecycle, one of these vehicles would have to amortize $1,700 to $3,400 in battery costs over 10 years before interest. At current fuel and electricity prices, a Smart Electric Drive covering around 10,000 kilometers (6,200 miles) per year would represent a cost saving of around $500 per year a gasoline-powered model. What's more, if in 2015 the government were to subsidize one of these cars to the tune of $2,400, buying an e-car would pay for itself in just two and a half years. Historically, that is equivalent to the proliferation of diesel engines that initially struggled to compete with gasoline models and became widespread only thanks to subsidies—either through taxation or the price of diesel.

## 7. The electrification of the automobile is compelling and inevitable

Automakers are already grappling with ever more stringent global $CO_2$ and environmental

Figure 6: Mass production will more than halve the cost of batteries before the end of this decade

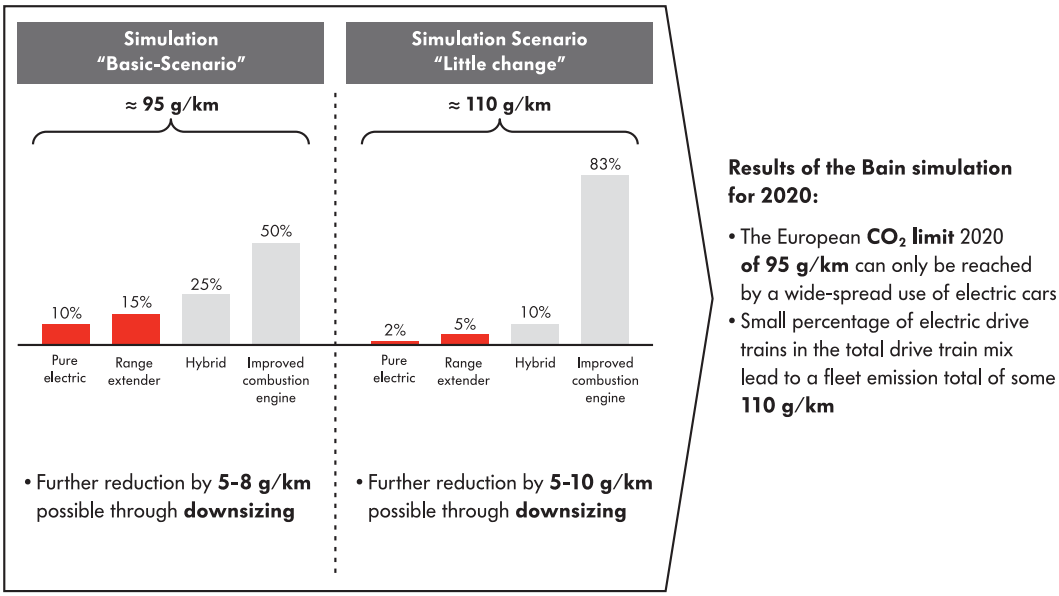



legislation. The recent announcement by US President Barack Obama that carmakers will be compelled to reduce drastically the fuel consumption of their engines is a case in point. Some manufacturers will have to slash the $CO_2$ emitted by their vehicles by 20 percent to 30 percent by 2015 or face substantial penalties. And that is just the beginning. By 2020 at the latest, for example, all car manufacturers in Europe will have to comply with a $CO_2$ limit of 95 g/km (see Figure 7). For some, that will mean a reduction of up to 50 percent compared with today. In the case of larger vehicles, this reduction will barely be achievable by such conventional means as the downsizing or turbo-charging of combustion engines.

Automakers have a variety of technological means to meet these climate protection goals. For example, they can cut fuel consumption by 3 percent to 5 percent by decoupling ancillary modules such as air-conditioning, power brakes and power steering. Through extensive simulations, Bain has analyzed the potential savings yielded by all the available means. Yet it is clear that the goals for 2020 can be achieved only if electric cars account for a high percentage of the vehicles sold. That means that many manufacturers will need to convert their large vehicles to hybrids and electrify their smaller ones on a large scale to reach the across-the-range target of 95 g/km $CO_2$.

Alternative technologies, such as hydrogen fuel cells, for example, are still some 10 years away from serious production. What's more, the efficient production of hydrogen as well as transport, storage and the development of

Figure 7: Large-scale electrification will be the only means by which to meet European $CO_2$ targets by 2020




H2-filling stations are still unresolved. Nevertheless, it remains important to invest in that technology, since it appears to offer the only alternative in the commercial-vehicle sector. Given the great weight of such vehicles and their loads, it is unlikely that battery power alone can offer a universal solution for trucks. Ultimately, a fuel-cell car is still an electric car, but with its own "power plant." That power plant could also be a high-efficiency combustion engine running on biofuels. With the right vehicle design, the power plant would be needed only on rare occasions to provide energy—for example, on trips exceeding 60 kilometers (37 miles).

Ambitious local and regional climate targets are here to stay—and inevitably, pave the way for greater e-mobility. A substantial proportion of the cars of the future will come equipped with an electric drivetrain, and will be powered either by a battery, combustion engine, fuel cell or a mixture of these.

## Conclusion: The race for the e-car has already begun. Those that wait too long will lose!

The race for leadership in e-cars goes beyond auto manufacturers—it encompasses regions, nations and governments. The new technology promises a transformational shift in the auto industry: With e-cars, once again, every manufacturer in every country is at the same starting line. As in all races, the first to accelerate is likely to lead the pack.

Recognizing that, governments across the globe are developing an e-mobility agenda to ensure

the competitiveness of their e-car industry. Japan, one of the first countries to commit to the development of electric cars, has long followed a collaborative approach. The government works with industry players in areas like policy and setting standards and encourages industry players to invest in technology and infrastructure development. The government has also invested about $330 million in R&D to develop battery technology.

In the UK, government sees electric vehicles as a means to an end of aggressively cutting $CO_2$ emissions. In the last few years, the UK government provided funding support to industry-led demonstration and collaborative R&D projects. And from 2011, UK consumers of electric vehicles can take advantage of subsidies of $3,000 to $7,000. London is leading the charge in e-cars; it provides free parking in many areas for e-vehicles, is aggressively switching the city fleet to electric autos and is building a comprehensive network of charging stations across the city.

Another aggressive player is Israel, where the government has "authorized" a private electric vehicle service provider to build and operate the infrastucture and ensure the growth of a vibrant e-car industry in the country. In China, too, the government is actively promoting the development and rollout of e-vehicles. The goal: to ensure that at least 5 percent of all passenger car sales in 2011 come from new energy cars.

With governments pushing the accelerator on e-vehicles, automakers realize they must change gears fast to service the growing demand for e-mobility. Joining the fray are major players with well-known global brands—as well as new entrants who are fast gaining ground with new offerings, in this suddenly level playing field.

The Chevrolet Volt from General Motors, the Nissan Leaf and the Mitsubishi i-MiEv will all be launched before the end of this year—the first e-cars developed and manufactured using genuine mass-production processes. The Chevrolet Volt is a true electric car, which also has a small combustion engine to extend its range. It is based on the concept of an e-car with its own on-board power plant (a "range extender"). From 2011, the Volt will also be marketed in Europe as the Opel Ampera.

Mitsubishi has already begun selling its purely battery-powered i-MiEV e-car—with a quoted electric range of around 160 kilometers—in Japan and England. PSA plans to market the e-car versions of the Peugeot and Citroen based on the i-MiEV while Renault will launch four different models before the end of this year.

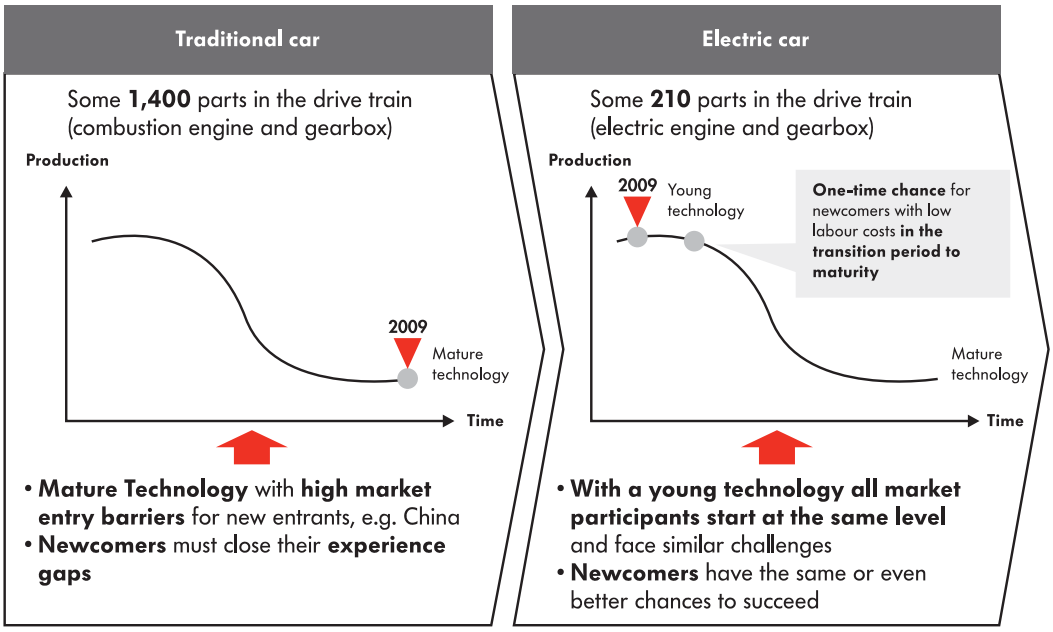
German auto companies are readying their offerings. Daimler's Smart Electric Drive is due to go on sale in 2012 and Volkswagen is expected to make its e-car debut with its ultra-compact Up model in 2014. BMW plans to launch a two-seater city car code-named Project i in 2013. Sensing the opportunity to emerge as leading players in an evolving e-car global market, China's auto manufacturers are taking aggressive steps to make their mark. China already hosts some of the world's leading battery manufacturers. Battery and automaker BYD is expected to launch an e-car for the US market this year. At the recent Geneva Motor Show, Daimler announced that it is embarking on an extensive venture with BYD for the joint development and production of e-cars.

Many more such collaborations will be the norm as the market for e-vehicles matures. Established auto manufacturers with leading auto brands will find consumers have a new

notion of "premium." New entrants in electric vehicles will bring innovative technology to the table, but over time will need to develop brands and distribution channels. All auto manufacturers will have to rethink strategy based on the consumer's emerging needs. Increasingly, for example, while buying cars people will not ask for mileage, but charging time—how far a car goes on a full tank will matter less to e-car owners than how quickly it recharges.

The e-car presents the automotive industry with the most important technological change in its 100-plus-year history. As established auto brands line up with new e-car companies, the field is once again open (see Figure 8). The market for e-vehicles may seem small right now—but it is slated to increase exponentially as e-mobility gathers momentum with better infrastructure, more government support and steadily increasing consumer demand. For automakers, parts suppliers or automobile manufacturing nations, the lights are flashing green. Those that are quick off the mark, change gears fast and ride over obstacles are likely to win the most ground.

Figure 8: The e-car opens up a whole new market and provides opportunities for new entrants



## Glossary

**Electric car (e-car):** An electric car has a drive system comprising a battery and one or more electric motors as the key elements. In principle, the battery is charged with electricity from an electrical outlet. Provided the battery is large enough (depending on the weight and size of the car), an electric car has a range of 150 to 200 kilometers (93 to 124 miles) before it has to be plugged back in. An electric car can be charged via any normal electrical outlet. Dependent on the residual charge and the size of the battery, the charging process takes between 15 minutes (for a heavy current charge) and eight hours (for a normal charge).

**Range extender:** To extend their range, some electric cars have their own "power plant" on board. These vehicles are called range extenders or serial hybrids. The power plant provides the electricity required to keep driving when the battery has been discharged. As a result, the vehicle is not dependent on lengthy charging times and is more flexible in range. The power plant may be a small gasoline or diesel engine that drives an electrical generator. Fuel cells that generate electricity directly from hydrogen can also be used as the power source.

**Plug-in hybrids:** Vehicles that can be driven both directly via a combustion engine and by an electric motor are called hybrids. If the battery of the independent on-board electric drive system is large enough, the car can also be charged from an electrical outlet—referred to as a plug-in hybrid, which also ranks as an electric vehicle since it can travel a certain distance entirely under electric power and without producing emissions. Today's plug-in hybrids have a purely electrical range of up to 30 kilometers (18.5 miles).

**Full/mild hybrids:** Classic full or mild hybrid cars cannot be charged from an electrical outlet. Therefore, they do not rank as electric cars, and are not a form of e-mobility. Nevertheless, this technology, in which the combustion engine is supported by one or more electric motors in specific driving conditions, does provide alternatives. The electric motors are powered exclusively by surplus energy released during braking, for example, and stored in a comparatively small battery. Particularly in the case of large, heavy or high-performance vehicles, some substantial savings can be made in fuel consumption and $CO_2$ emissions. This technology can also be seen as a transitional solution on the way to electro-mobility.

## Notes

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