China Charges Up: The Electric Vehicle Opportunity

October 2008

Paul Gao
Arthur Wang
August Wu

The authors wish to thank Glenn Leibowitz and Joyce Hau for their contributions to this report.

McKinsey&Company

China Charges Up: The Electric Vehicle Opportunity

Faced with high energy costs and rising consumer and government concern over the fate of the environment, the world's automakers are stepping up investment in the development of alternative powertrain technologies that promise to substantially cut fuel consumption and reduce greenhouse gas emissions.

Much attention to-date has focused on advances by Japanese and American automakers in the development of hybrid and battery electric vehicles. Toyota's Prius has emerged as the best-selling hybrid car in the world. Tesla Motors, a US-based start-up, has launched its first battery electric vehicle, the Tesla Roadster. By the end of 2010, GM plans to launch its much-touted Volt hybrid, while Chrysler has recently announced similar plans.

As the media shines its spotlight on technological advances in more developed markets, China is quietly laying the foundation to become a global contender in this emerging industry. Already the world's second-largest automobile market, China is set to overtake the United States as the world's biggest by 2030. If China's car fleet grows at the current rate of 12 percent a year, another 270 million vehicles will be added to China's roads in the next 25 years. By 2030, the total number of vehicles could reach 287 million – or about 30 percent of the world's automobiles by then.

Unless China adopts newer technologies that are substantially more fuel-efficient and environmentally-friendly, such a large automobile fleet will place enormous strain on energy resources and the environment. Assuming the continued predominance of gasoline and diesel-powered automobiles, China will need to import 6.2 billion barrels of oil to fuel its domestic automobile fleet in 2030. By then, China's passenger vehicles could be responsible for generating as much as 20 percent of global passenger vehicle CO_2 emissions.

We recently conducted a global study of several alternative automobile powertrain technologies, comparing them to the traditional internal combustion engine (ICE) along a number of dimensions, including total cost of ownership, potential to reduce greenhouse gas emissions, and savings on imported fuel. (see sidebar, "About the study") Of the various alternatives available to China's automakers – electric vehicles, including plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV); full hybrid vehicles; compressed natural

gas (CNG) vehicles; as well as vehicles with improved gas and diesel-powered internal combustion engines – electric vehicles stand out for their potential to comprehensively address some of the biggest issues concerning cost, energy consumption, and environmental impact.

In addition to reducing energy consumption and cutting greenhouse gas emissions, by embracing the development and production of electric vehicles, China has an opportunity to establish a global position in this nascent but rapidly growing market. The opportunity could be very attractive indeed: we estimate that the domestic market for electric vehicles in China alone could reach 700 billion to 1.5 trillion renminbi by 2030, assuming that electric vehicles make up 20 to 30 percent of the total passenger vehicles market by then. The total market for electric vehicles in North America, Europe and Asia is forecast to reach $80 to $120 billion by 2030, assuming a 5 to 10 percent penetration of electric vehicles by then.

Given the enormous challenges that lie ahead, government will play a critical role in transforming electric vehicles from a vision into reality. The Chinese government has been actively promoting the development of the electric vehicle industry, from providing research institutes and industry players with R&D funding, to rolling out fleets of electric vehicles and recharging facilities in several pilot cities.

ABOUT THE STUDY

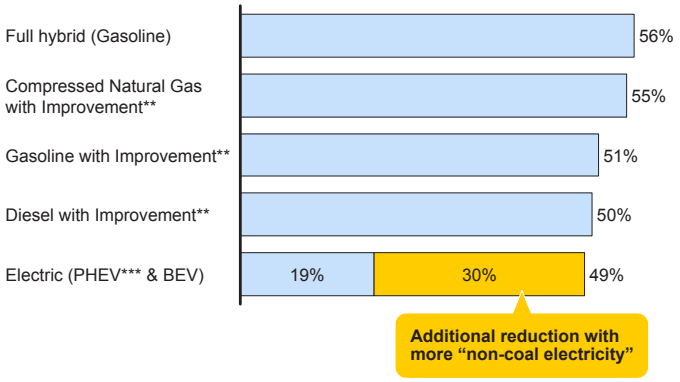
Over a period of 8 months in 2008, a global McKinsey team studied the passenger vehicle industries in North America, Europe, China, and India. The team examined four powertrain technology alternatives, chosen on the basis of existing technologies and their near-term commercial feasibility. We contrasted them to conventional internal combustion engine (ICE) vehicles that run on gasoline or diesel

- **Improved gasoline and diesel vehicles:** Traditional internal combustion engine (ICE) vehicles that are outfitted with emission-reducing technologies, such as variable valve controls, which help engines burn fuel more efficiently, and low rolling resistance tires, which save fuel by reducing friction. Improved ICE vehicles could have a life-cycle carbon abatement potential of up to 51 percent in China (Exhibit 1).

Exhibit 1

NEW POWERTRAIN TECHNOLOGIES CAN SIGNIFICANTLY CUT CARBON EMISSIONS

Life-cycle carbon abatement potential* of various powertrain technologies compared to today's gasoline-powered internal combustion engine



* Including emissions produced by the vehicles as well as those produced during the entire carbon life-cycle of the vehicle, from power generation to the transportation of fuel
** Assuming the same type of improvements are applied to gasoline, diesel, or CNG vehicles
*** Emissions in PHEV electric mode
Source: McKinsey analysis

- **Full hybrid vehicles:** Running primarily on gasoline, full hybrids are powered by a battery during acceleration of the vehicle, but draw most of their power from an internal combustion engine. Full hybrids, equipped with ICE improvement technologies mentioned above, have a life-cycle carbon abatement potential of 56 percent in China.
- **Compressed natural gas (CNG) vehicles:** CNG vehicles are normally perceived to be a source of clean energy, but their life cycle carbon abatement potential depends wholly on the source of the gas – the greater the distance the gas needs to be transported, the higher this powertrain's "well-to-tank" emissions. CNG cars rank close to hybrids in their life-cycle carbon abatement potential at 55 percent in China, assuming the gas comes from local sources.
- **Electric vehicles:** Electric vehicles include plug-in hybrid vehicles (PHEV) and battery electric vehicles (BEV). Compared with full hybrids, plug-in hybrid vehicles contain a much bigger battery that can power the vehicle for a longer distance without the aid of an internal combustion engine, can be recharged by plugging them into standard electric sockets, and derive a smaller proportion of their propulsion from the internal combustion engine. Battery electric vehicles run

solely on battery power without the aid of any internal combustion mechanism. Given China's reliance on coal-fired plants for electricity, electric vehicles today only have a 19 percent carbon abatement potential over current internal combustion engine technologies; however, this can be increased to as much as 49 percent if China diversifies its energy mix towards alternative energy sources for its supply of electric power.

The team evaluated these alternative technologies along four dimensions: oil imports savings potential, carbon emissions abatement, total cost of ownership (TCO) to consumers, and innovation opportunities for Chinese OEMs and suppliers.

We tested the life-cycle carbon abatement potential from China's car market under three potential scenarios. In the "frozen technology" scenario, a base case scenario that assumes the continued use of current technologies, CO_2 emissions could reach nearly 1.2 billion tons by 2030. In addition to this control scenario, we looked at another "rational consumer" scenario that assumed consumers would buy cars at the lowest total cost of ownership. In a contrasting "best for society" scenario, we assumed that consumers would pay for the best carbon abatement technology, regardless of cost.

Depending on which technologies consumers actually buy, China could reduce CO_2 emissions from passenger vehicles by up to 20 to 40 percent by 2030, and significantly cut reliance on foreign oil imports.

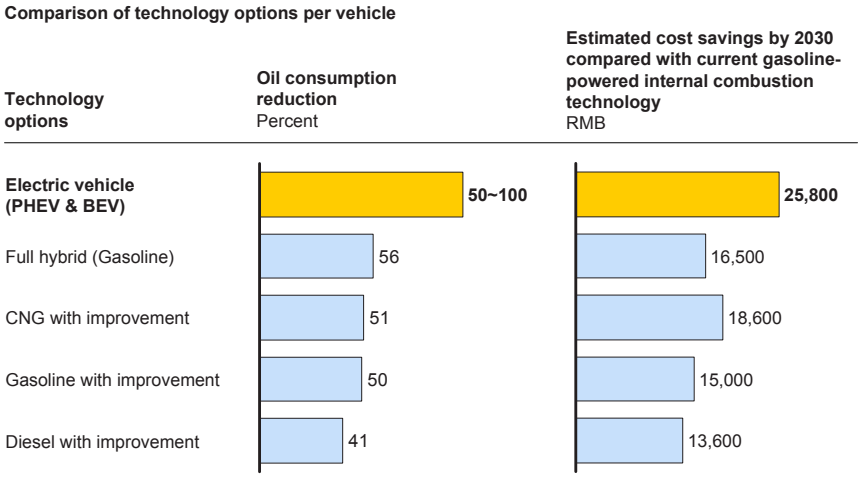
BENEFITS OF ELECTRIC VEHICLES

In comparing the various powertrain technologies, we looked at the savings in oil consumption, potential for abatement of greenhouse gas emissions, total cost of ownership, as well as the potential for China's domestic auto industry to develop homegrown technologies that are domestically and globally competitive.

Despite a moderately lower potential to reduce carbon emissions compared with other technologies, electric vehicles scored favorably against other technologies along all other criteria (Exhibit 2).

Exhibit 2

ELECTRIC VEHICLES OUTSTRIP OTHER POWERTRAIN TECHNOLOGIES IN THE REDUCTION OF OIL CONSUMPTION AND COST SAVINGS



Source: McKinsey analysis

Reduced oil consumption

Electric vehicles have a clear-cut advantage over other technologies when it comes to reducing fuel consumption. Whereas other technologies promise a reduction in per-vehicle gas consumption of 41 percent to 56 percent, electric vehicles can cut gas consumption by up to 100 percent.

Given China's rapidly growing automobile fleet, such savings could translate into an enormous reduction in oil consumption, and therefore oil imports, depending on the proportion of electric vehicles in the market. Today, China imports 3.4 million barrels of crude oil per day, representing 48 percent of its total oil consumption. If, however, 30 percent of all cars in China by 2030 were electric vehicles, China could save up to 700 million barrels of oil, or 10 percent of the estimated 6.2 billion barrels of oil it is projected to need by then.

Total Cost of Ownership

Affordability is a key factor driving the consumer take-up of new powertrain technologies. In calculating the total cost of ownership among various competing powertrain technologies, we took into account the initial cost of the vehicle, its resale value, as well as the estimated fuel savings, assuming an average ownership period of 5 years.

Not surprisingly, electric vehicles are substantially more expensive than standard internal combustion engine automobiles. Based on current projections and industry announcements, consumers will need to pay an additional estimated 30,000 renminbi for a plug-in hybrid electric vehicle in China, a 25 percent premium over standard gasoline-powered passenger vehicles.

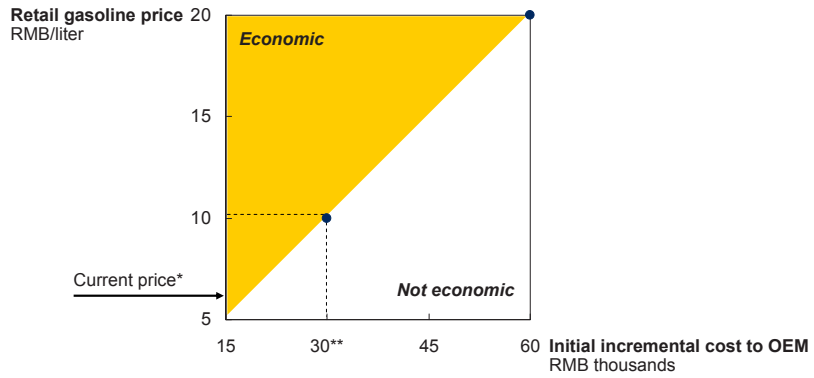
Recouping this premium in the form of fuel savings, however, may not be so straightforward for consumers in China. Government regulation of gasoline prices has largely insulated Chinese consumers from the increase in the price of oil that has afflicted the rest of the world over the past year. Recent signs indicate, however, that the Chinese government intends to gradually adjust gasoline prices upwards: in July 2008, the price of gasoline edged up by 17 percent to about 6.6 renminbi per liter.

If gas prices reach more than 10 renminbi per liter, we estimate that consumers will fully recover the premium they will need to pay for their electric vehicles within five years (Exhibit 3). Although further deregulation of prices seems imminent, the extent to which gasoline prices will change still remains unclear. Many factors can affect electric vehicles' incremental cost to OEMs and consumers in the near term. In the long term, however, as gasoline prices adjust and as technology improves, electric vehicles could well become an economically viable option for the average consumer in China.

Exhibit 3

RISING GAS PRICES IN CHINA WILL MAKE ELECTRIC VEHICLES A MORE AFFORDABLE CHOICE FOR CONSUMERS

Economic benefit of plug-in hybrid vehicle* under different initial incremental costs and fuel prices



* In October 2008, the retail gasoline price in China ranged between 6.37 RMB/liter to 6.78 RMB/liter
** Projected incremental production cost for BYD's new plug-in hybrid versus its gasoline model
Source: Press articles; McKinsey analysis

Carbon abatement potential

One of the primary benefits of electric vehicles is, of course, the reduction of greenhouse gases emitted into the atmosphere. Our calculation of the total carbon abatement potential of alternative powertrain technologies counted not only the CO_2 emissions that vehicles produce, but also emissions produced throughout their entire life-cycle, from the CO_2 emitted during the generation of electric power through to the transportation of fuel.

With no concerted action to adopt new powertrain technologies, the level of CO_2 emissions from passenger cars in China could reach nearly 1.2 billion tons in 2030. However, our research showed that by adopting a mix of various alternative powertrain technologies, China could cut emissions from passenger vehicles by up to 45 percent.

Relative to other powertrain technologies, electric vehicles demonstrate a somewhat weaker carbon abatement potential. While full hybrid cars have an abatement potential of 56 percent, electric vehicles' potential stands at 19 percent. This can be explained by the fact that China still relies on coal-fired plants for as much as 85 percent of its electricity supply.

However, if alternative energy sources account for 50 percent of China's supply of electricity by 2030, the carbon abatement potential for electric vehicles rises to 49 percent, roughly on par with other technologies.

Laudably, the Chinese government is pursuing a number of initiatives aimed at developing sources of alternative energy such as wind, solar, nuclear and hydro-power in order to reduce reliance on highly polluting coal. A Renewable Energy Law passed in 2006 set the ambitious target of making renewable energy constitute 10 percent to 15 percent of China's total energy consumption by 2010.

In a bid to move away from its reliance on coal-fired power generators, China's top planning body, the National Development and Reform Commission (NDRC), has set mandatory targets for increasing the share of alternative energy used by the national power grid to 30 percent by 2030. In addition to reducing greenhouse gas emissions from power plants, such a move would significantly increase the carbon abatement potential of electric vehicles.

The Chinese government has also demonstrated its commitment to combating car emissions by instituting high fuel economy standards: since the beginning of 2008, it has required all Chinese manufacturers to ensure that new cars achieve a minimum mileage of 37 miles per gallon.

Building a homegrown electric vehicle industry

Since the adoption of the 11th Five-Year Plan in 2006, the Chinese government has made "independent innovation" the cornerstone of domestic industrial policy. Aimed at pulling China up the value-added ladder, this policy encompasses a number of initiatives to promote investment in research and development across several strategic sectors, including the auto industry.

While China has built a large and rapidly growing automobile assembly industry, it still substantially lags other countries in the development of existing powertrain technologies. US and Japanese firms dominate the traditional gasoline-powered vehicle sector, while Europeans rule the diesel sector. Japanese firms such as Toyota and Honda lead in the hybrid vehicles market. While a handful of firms in Japan and North America are making strides in developing electric vehicles, no nation has yet emerged as the clear leader in this sector.

With concerted action by the public and private sectors, China may have an opportunity to establish a foothold in this nascent industry. Developing a homegrown electric vehicle industry in China could serve several purposes: in helping China wean itself from reliance on foreign powertrain technology; in creating a new multi-billion dollar industry for auto assemblers, parts makers, and infrastructure providers; and in creating a platform for China to compete globally by leveraging its superior cost advantage over developed markets.

Some Chinese companies are making strides in bringing electric vehicles to market. Tianjin-Qingyuan Electric Vehicle Company is building a factory that will produce 20,000 electric vehicles a year, of which half are slated for export. Shenzhen-based BYD, the world's leading manufacturer of rechargeable batteries, has announced it will launch a plug-in hybrid electric car at the end of 2008, and it plans to launch a battery electric car by the end of 2009. In September, MidAmerican Energy, an energy-services provider controlled by Berkshire Hathaway, took a 10 percent stake in BYD, and announced plans to market its electric vehicles to the US and European markets.

Chinese auto-parts suppliers also stand to benefit greatly from the potential boom in electric vehicle manufacturing. Demand is set to rise for the most important components in electric vehicles, such as batteries, electric motors, generators, as well as non-powertrain parts such as air-conditioning systems.

According to our estimates, the market for electric vehicle batteries in China could reach 150 to 400 billion renminbi by 2030, assuming a 20 to 30 percent penetration rate of electric vehicles, and an average cost of 30,000 to 50,000 renminbi per battery.

Some Chinese companies have become active players in the global supply chain for electric vehicle batteries. Thunder Sky Energy Group, a Shenzhen-based lithium-ion battery manufacturer, supplies batteries that are used in electric buses in the US, Japan, Italy, and Finland.

Electric vehicles will also create opportunities for software developers. Electric vehicles require an electronic interface that informs the driver of the status of the car's vital statistics, from fuel and battery usage, to split-second updates in GPS navigation systems. Venture-backed start-up Better Place is developing a comprehensive information management system it calls AutOS

that will, among other things, inform the driver of the nearest battery-charging stations.

While other technologies such as fuel cells hold great promise in reducing CO_2 emissions, its commercial application remains years away. Investing in electric vehicles, however, does not mean Chinese OEMs and suppliers should stop their research into other technologies. Rather, they should maintain a balanced technology portfolio, with electric vehicles being a near-term solution, while viewing other technologies such as fuel cells as a potential long-term solution that could yield returns once the technology becomes commercially viable.

Advantages for Power Providers

Electric vehicles present an opportunity for China's power companies to more efficiently manage their generating capacity by making use of under-utilized capacity at night, while mitigating demand during the day. Currently, power companies' generators run idle in the night because of low demand. (Shutting down the generators entirely is not an option, as the energy required to restart them is greater than the energy lost while letting them run idle.) By allowing electric vehicles to charge up at night, electric vehicles could make use of power that would otherwise go to waste. Night-time charging will reduce demand for power during the day, therefore reducing strains on capacity. In particular, stored energy from car batteries could serve as a buffer for periods of peak demand, reducing the strain on the power grid.

CHALLENGES, SOLUTIONS, AND OPPORTUNITIES

Recharging infrastructure and advances in battery technology are two of the most critical enablers of the electric vehicle industry. Industry players, in collaboration with the government, will have to address these issues head-on if they hope to build a viable homegrown electric vehicle industry.

Recharging infrastructure

Electric vehicles won't get very far without having somewhere for drivers to recharge or replace their batteries. Installing a widely available battery-recharging infrastructure will be a critical factor to the take-up of electric vehicles.

But building the infrastructure to accommodate electric vehicles in China will not come cheap. An estimated 5 to 10 billion renminbi will be needed by 2020 to install the necessary recharging facilities in China.

Recently, State Grid Corporation, China's largest electric power provider, announced the construction of charging stations for electric buses and passenger vehicles in Beijing, Shanghai and Tianjin.

Installing enough charging stations is only half the battle, however. While filling a gasoline tank usually takes only a few minutes, given the limitations of today's technology, fully charging an electric vehicle could take several hours. In Israel, Better Place has proposed a scheme where drivers could exchange used batteries for fully-charged ones at swapping stations in just two to three minutes. Car owners would lease the battery, substantially reducing the upfront cost of the electric car itself.

Battery technology

One of the biggest issues facing the potential take-up of electric vehicles is the rate of improvement in the performance of electric vehicle batteries. The biggest drag on electric vehicle performance comes from the lithium-ion battery, which can add another 220 kilograms to the total weight of a car, versus an ICE-powered vehicle.

Since most passenger vehicles in China today are driven in urban areas, where shorter distances and slower speeds are the norm, this may not prove to be as

vexing an issue as it is in other markets such as the US or Europe, where the average driving distance and top speed are considerably longer and higher.

Continued research and development into electric battery technology is generating promising improvements in performance. US-based A123Systems, one of the world's largest producers of high-power lithium-ion batteries, announced a battery capable of powering a car for 200 kilometers between charges. Toshiba recently announced the commercial launch of its Super Charge battery, which can be charged to 90 percent capacity in less than five minutes.

The guiding hand of government

China has a compelling case for embracing electric vehicles. Electric vehicles represent China's chance to significantly cut greenhouse emissions, reduce oil dependency, and become a relevant player in the global electric vehicle market.

The Chinese government has already taken a number of substantive actions to kick-start the development and adoption of electric vehicles. The Ministry of Science and Technology, which oversees China's auto industry, is actively encouraging the development of alternative engine technologies. The Ministry has mandated that 10 percent of China's cars must run on alternative fuels by 2012. To support this ambitious goal, the Ministry has launched the "863 plan," an initiative to funnel money into research and development of EV technology. The Ministry has also recently announced a plan to roll out 10,000 hybrid, electric and fuel-cell vehicles in 10 cities around China by 2010.

In addition to funding, the Ministry could also facilitate the development of electric vehicle technology by implementing industry-wide standards that govern the technical specifications of electric vehicles. Such standards would lower the technical entry barriers and costs to companies and academic institutions investing in electric vehicle research.

Tax incentives can encourage consumer take-up of more fuel-efficient vehicles. On September 1 2008, a "green" tax went into effect that is aimed at encouraging consumers to switch to smaller, cheaper, and more fuel-efficient vehicles. Taxes on vehicles with engine capacities over 3 liters were increased to 40 percent, whereas taxes on the smallest cars, with engines under 1 liter, were reduced to 1 percent.

The government can also accelerate the introduction of the long delayed fuel tax, which will not only help make electric vehicles more economically viable than ICE vehicles in China, but also help shift government spending from subsidizing oil and gas companies to providing incentives to companies and research institutes that develop alternative powertrain technologies.

And through collaboration with power companies and automakers, the government can facilitate the roll-out of recharging stations. For example, Better Place and Renault-Nissan are partnering with the governments of Israel and Denmark to deploy an electric vehicle recharging grid by 2011 that will be powered by solar and wind energy, respectively.

Conclusion

In the early part of the twentieth century, Henry Ford's mass assembly line revolutionized car manufacturing, putting American automakers at the forefront of the industry. As the oil crisis of the 1970s roiled an industry dominated by gas-guzzlers, Japanese automakers launched a second revolution with the mass marketing of far more fuel-efficient compact cars.

Today, the global auto industry stands at a cross-roads: the imminent slow-down in the global economy, a continued reliance on expensive and insecure fossil fuels, and growing concern over global warming, are creating much uncertainty, as well as opening up new opportunities. China, with its large supply of low-cost labor, a rapidly growing auto market that offers scale economies in production, and the explicit support of a government committed to weaning itself off imported oil and cleaning up the environment, could become a pioneer in the conversion of electric vehicles from an expensive niche technology, to an affordable, widely-used technology. It remains to be seen how government policy and industry dynamics will play out, but China is faced with a unique opportunity to reshape the global auto industry, one that holds the promise of substantial economic and social benefits for consumers.

About McKinsey & Company's Automotive and Assembly Practice in Greater China

McKinsey's Automotive and Assembly Practice serves domestic and multinational clients in virtually all areas of the automotive and assembly industry. Industries served include automobiles, trucks and buses, automotive distribution and retail, automotive supply, machinery, mechanical and electrical components, and plant construction. Our consultants have deep functional expertise in nearly every aspect of the value chain, including product development, manufacturing, purchasing and supply, as well as in branding, distribution, and retailing.

For more information

Please contact Shirley Xia at Shirley_Xia@mckinsey.com

October 2008
Design New Media Greater China

McKinsey&Company