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## Review of Electric Vehicle Technologies Progress and Development Prospect in China

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### Abstract

Developing electric vehicles (EVs) has been chosen as national strategy as solution to energy security and urban air pollution by China. China has invested much to develop electric vehicle technologies. In past 15 years, the EVs technologies have improved greatly, and in public serving field, the electric vehicle were used in large-scale. The traction battery and electric motor technologies were improved distinguished. By the EVs demonstration programs, the mainstream technology roadmap in line with China's national conditions is becoming gradually clear.

In this paper, the progress of China EVs technologies breakthrough and industrialization, pushing policies (government and local government) were summarized. The progress on EVs demonstration program was reviewed and the effectiveness was evaluated. The technology roadmap of traction battery, fuel cell, and electric motor for EVs in past years was concluded. The different technological roadmaps were evaluated by effects in demonstration program.

Based on the review of the progress of China EVs R&D and demonstration program, the existing problems and future challenges in EV development were put forth. And the future electric transportation in China was proposed, including electric powertrain technologies roadmap, electric car model strategy, EV industrialization strategy.

*Keywords: electric vehicles, traction battery strategy, EV demonstration, China electric powertrain roadmap,*

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## 1 Introduction

China is facing urgent energy security and urban air pollution problems. The issues of PM2.5 harmful to human health has caught highly concern of China government. The tailpipe emission is the main source of harmful PM2.5 in China[1-3]. Electric vehicles (EVs) are becoming

of increasing interest in world with an intensified focus on the climate and CO<sub>2</sub>-emissions.

China has issued many policies to push the EVs development. Since the 10th 5-year plan of developing energy saving and new energy vehicles, China has invested more than 100M RMB for EVs key technologies break through and industrialization. In 11th 5-year plan, 1.16 billion RMB had been invested in EVs R&D. In 12th 5-

year plan, China MOST will invest 3billion into electric vehicle technology researching [4-6].

## 2 Pushing policies for electric vehicles in China

### 2.1 Government activities

Setting aside corporations, the two key activist organizations affecting the adoption of EVs within China are the Ministry of Industry and Information Technology (MIIT) and Ministry of Science and Technology (MOST). While MOST is focused on directing R&D efforts, MIIT is dedicated to regulating and developing major industries.

China government has initiated many policies to support electric vehicle development, including subsidy, some tax reduction and exemption, and having priorities in some aspects. Hybrid vehicles can receive five different levels of funding under China's "Ten Cities, Thousand Vehicles" new energy vehicle pilot programme. The highest subsidy amount is RMB 500,000 for battery electric bus in public transportation, and hybrid electric buses usually qualify for a highest subsidy of RMB 420,000 based on fuel saving ratio[7-9].

Furthermore, the Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology and the National Development and Reform Commission jointly issued a new subsidy policy, giving private buyers in Beijing, Shanghai, Changchun, Shenzhen, Hangzhou and Hefei an extra subsidy for purchasing plug-in electric vehicles, either hybrid or pure electric. For every kW of battery capacity, a subsidy of RMB 3000 would be given to the buyer, giving PHEVs a maximum subsidy of RMB 50,000, and BEVs a maximum subsidy of RMB 60,000[10].

In Beijing, Shanghai, Hangzhou, Changchun, Shenzhen, Hefei, private purchasing of electric vehicle can get the government subsidy and local government subsidy, up to 120 thousands Yuans[11-12]. Both above mentioned problems are rooted in traction battery parameter optimized design to obtain the competitive advantage in the market.

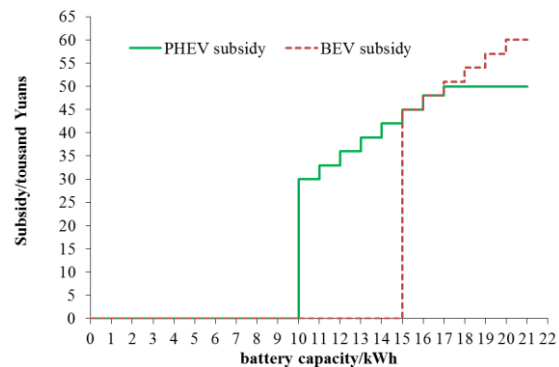


Figure 1: subsidy policy for EV by China government

In addition many incentive policies have been issued to promote development of electric vehicles technologies and industrialization, including relief of travel tax, free to get license plate [13]

In newly released 'accounting methods for corporate average fuel consumption of passenger cars', it is stated that the electric vehicle and plug-in electric vehicle with AER more than 50km can be ranked as zero fuel consumption and the numbers can be accounted as 5 times[14].

## 3 Electric vehicle technologies in China

### 3.1 Progress on traction battery

China is one of the world's major battery producers. BYD, BAK and Lishen battery companies, amongst others, produce most of the lithium-ion batteries for consumer electronics, particularly for mobile phones and computers. Today, a great deal of research is underway regarding battery development for the auto sector. The traction battery technology has been recognized as most important technology of EVs. China government has placed more importance on the advanced traction battery R&D. There were 3 traction battery technology systems in China based on cathode material, Lithium iron phosphate (LFP), lithium manganese oxide (LMO) and nickel-cobalt-aluminum (NCA) or nickel-cobalt-manganese (NCM). In China traction battery industries, the anode material almost entirely is graphite. The LFP accounts for most shares in EVs application[15].

In recent years, the traction battery technology has had a major breakthrough. In 2012, the power density of power type Lithium-ion battery was improved by 4 times from 2002 (491W/kg). Max specific energy density has reached to 134.4Wh/kg (cell level)[16].

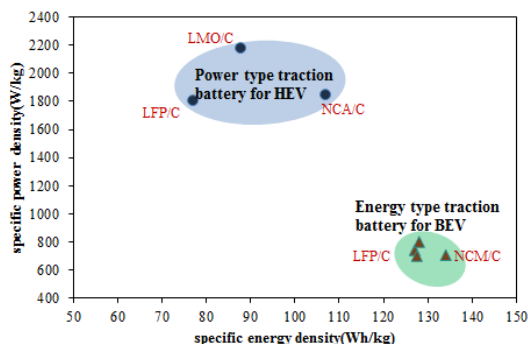


Figure 3: Technology status of traction battery for EVs in China

In addition to the great progress on technology breakthrough, the battery cost also was decreased greatly. In 2009, the lithium battery pack cost is 5RMB/Wh. By the end of 2012, the pack level cost of lithium battery (LFP/G) is about 3RMB/Wh. There is an evident downward trend.

### 3.2 Progress on traction motor for Evs

Based on the advantages of traction motor, there are two kind of technology roadmap. The widely used traction motor type includes Permanent magnet synchronous motors and AC asynchronous motor in China. The former was usually applied by electric car due to its high power density, and the later was adopted by electric bus due to its lower cost. Only a few company developed Brushless DC motors and switched reluctance motors [17]. The power density of high performance traction motor has reached to 2.68 kW/kg, and the system efficiency is more than 94%. The series products of 90 ~ 200kW for electric bus and 3 ~ 90kW for passenger cars have been formed. The annual production capacity of key traction motor company is above 10 thousands level.

### 3.3 Progress on fuel cell technologies

China mainly focuses on PEM fuel cell technology. The cost and duration are the main issues for fuel cell.

The duration of fuel cell stack was increased and cost was fallen dramatically. Specific volume power density of fuel cell stack module reached to 1000W/L. As for the low temperature performance, fuel cell stack can start at  $-20^{\circ}\text{C}$ , and system can start at  $-10^{\circ}\text{C}$ . Duration time reached to 3000 hours[18-19]. The fuel cell stack production capacity reached to thousand sets.

### 3.4 Progress on electric vehicles

Companies in China mainly focus on small to compact electric sedan, and the typical prototype of battery electric car are shown in table1. The all electric range is tested under NEDC. It can be seen that the cost is too high to competitive with conventional vehicles.

Table 1: parameters of typical battery electric cars in China

Manufacturer	EV Model	AER,km	Price, Thousand RMB
BYD	E6	160	300
SAIC	E50	140	235
JAC	iEV	100	150
BMEV	E150	110	240

## 4 Progress on EV demonstration programs in China

### 4.1 Overall progress on EV demonstration programs

The electric vehicle demonstration program had begun from 2006 by China government. The progress of the China EVs demonstration was shown in figure 4.

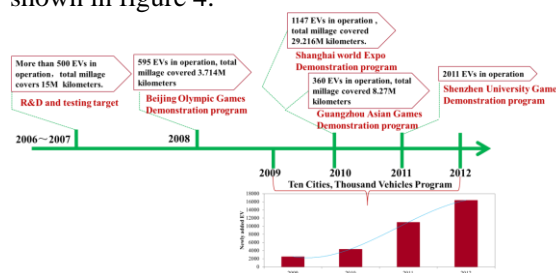


Figure 4: EV demonstration history in China

In 2009, the Chinese government initiated the 'Ten Cities, Thousand Vehicles Program' to stimulate electric vehicle development through large-scale pilots in ten cities, focusing on deployment of electric vehicles for government fleet applications. The Program has since been expanded to 25 cities and includes consumer incentives in five cities. Significant electric vehicle (EV) technology development in China is occurring in industry as well as universities, focusing primarily on batteries and charging technology. The new EV value chain

is beginning to develop new businesses and business models to provide the infrastructure, component, vehicle, and related services necessary to enable an EV ecosystem.

By the end of 2012, there are about 27.4 thousands EVs running in 25 demonstration cities in China[20]. The electric sedans sales increased greatly compared with last year, but still were niche market in China. There will be a long distance for EVs to mass penetration in China.

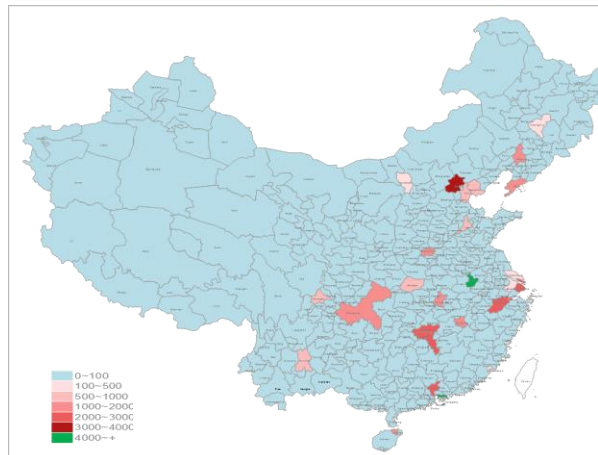


Figure 5: Progress on Ten cities Thousand vehicles program of China in 2012

From the statistic data, we can see that it is hard to promote electric vehicle sales in private application area.

Table 2: electric car for private users by the end of 2012[20]

Cities	EV number
Hefei	3038
Shanghai	46
Hangzhou	334
Shenzhen	982
Total	4400

#### 4.2 New business models for EV promotion in China

In order to mitigate the barriers of EV mass penetration, such as higher upfront cost, limited serving life of battery, immature infrastructure, limited range, inconvenient charging, etc., the new business model to promote EVs were tried and tested in China, including battery swapping, fast charging, battery leasing, electric car leasing by month, day or hour, finance leasing.

Hangzhou is a typical example of battery swapping&leasing business model. The battery is owned by China State Grid.

The charging mode is adopted by Shenzhen. In Hefei, the main electric vehicle promotion strategy is finance leasing mode.

## 5 Electric vehicle technologies outlook of China

### 5.1 Problems and challenging

Full hybrid electric vehicle is technological backwardness. The dedicate engine, electro-mechanical coupling and AMT technologies are immature. The configuration and control strategy of hybrid powertrain is not optimized enough, so the real fuel saving ratio unstable. The purchasing price and using cost is fairly high due to not reaching economic batch.

For pure electric vehicle, the key technologies still fall behind the advanced level in world, such as the traction package technology, thermal management, some key component of electric motor (IGBT, film capacitors) still rely on import.

An area of battery production where China's industry is strong is cathode and anode materials. This is primarily because there is a sufficient supply of these raw materials, such as lithium carbonate resource. In the lithium traction cell level, China is close to the international advanced level, but in pack level, China laggess behind much. As for next generation electric powertrain, core technologies need to breakthrough, especially some low cost technologies, such as low Pt consumption technology, key material localization. The fuel cell stack duration performance (3000h) is far below that of advanced level (more than 10,000h) in the world. High pressure hydrogen filling technology needs to be improved further. In addition, the fuel cell electric vehicle demonstration should be expanded in future.

### 5.2 Overview of overall EV developing strategy

Faced with the challenges mentioned above, China government set up the EV R&D layout shown in figure 6. It describes technology development in China as a "three-by-three" effort. The vertical columns distinguish the platforms of hybrid electric vehicles, battery electric vehicles, and fuel cell electric vehicles. The horizontal rows outline the key technologies that need to be developed to

support all these modes: energy storage systems drive train systems, and vehicles. The focus is placed on HEV, electric powertrain and fuel cell electric vehicle. The core technologies include energy storage, electric motor assembly and electronic control. The supporting platform must be attached importance to EV promotion, including standards and testing platform, infrastructure platform and application and demonstration city group.

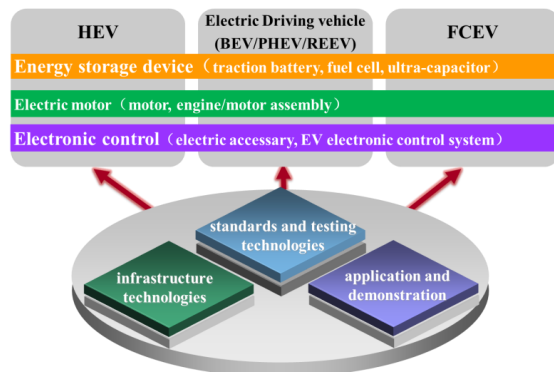


Figure 6: layout of EV R&D in 12<sup>th</sup> 5-year plan of China

### 5.2.1 The union-platform strategy for e-powertrain

China has the largest production and sales market of electric two-wheelers and the stock has reached 180 million, which is most unique in the world. In 2012, the total electric bicycles sales are 35.05 million, accounting for 90% share of world market[21]. Based on this industry, the traction battery and motor technologies can be improved by huge electric mobility platform, so as for cost reduction. Recent years, the share of lithium battery application on electric bicycle has increased greatly. In 2010, the population of lithium battery electric bicycle was 400,000, in 2011 was 650,000 and in 2012 the number was increased to 1.7 million with increasing ratio of 325% compared with that of 2010[22]. The researching results by Roland Berger show that volume production cost accounts for 60% of total cost of traction battery in small scale production stage [23]. The huge population of electric two-wheelers updated with lithium battery will lead to lithium battery price decreased sharply. So the electric two-wheeler market is one of platform for electric car in China from views of technologies development and cost reduction.

Another important type of special electric mobility in China is the low-speed rural electric vehicle. These vehicles, now mainly powered by lead-acid batteries, are not officially licensed for

use on roads, but have nonetheless seen production numbers of over 50,000 per year, with several factories, such as Shandong Shifeng and Hebei Yujie. According to interviews, these low speed rural e-vehicles travel up to 60 km per hour, over distances of up to 80 km per charge, not unlike vehicles known as “Neighborhood Electric Vehicles” in the United States. The vehicles are manufactured by agricultural equipment firms, and are distributed along the same channels as agricultural vehicles. Since the main market is in rural communities, finding spaces for charging is not an issue, as most rural families live in single-family dwellings where there is room for parking and use of extension cords can ensure supply of power to vehicles to charge overnight[24]. In future, this kind of low speed electric vehicle will be mass promoted in rural and suburban areas. By the end of 2012, it is reported that the population of low speed electric vehicles operating in China have increased to 100,000.

So for the traction battery widely applied, the battery should be designed by standard module to fit for all kind of electric mobility including light weight electric vehicle (including electric two-wheelers, electric three-wheelers, and electric quartercycle), electric car and electric bus. Based on analysis above mentioned, the module strategy of key component of electric vehicle is the one of the core concept for China state EV technology roadmap.

In other hand, in conventional car field, China has more advantages in small-displacement (below 1.6L) car. So the small displacement engine and traction motor can be modulated as mech-electric coupler assembly of hybrid electric vehicle. So the small displacement engine with electric motor system also can be modulated as key component for all kind of hybrid electric vehicles, including different hybrid modes, such as electric-electric hybrid, gas-electric hybrid and oil-electric hybrid.

The core concepts of e-powertrain of China can be summarized as module, integration and uni-platform (see figure 7).



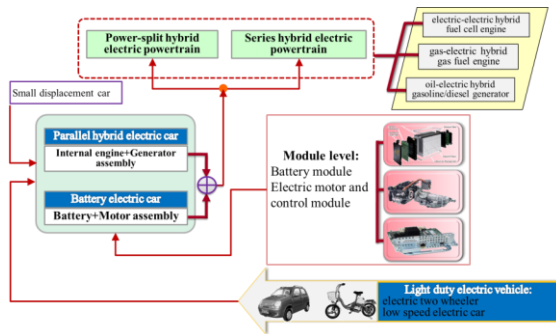


Figure 7: electric uniform powertrain technology roadmap of China

Target to China Long Term Development Plan, energy-efficiency vehicle technology and electric driving technologies all play important role in solving the problem of energy security, local emission, and climate change. The the overall technology roadmap is the energy-efficiency and new energy vehicle shoule be developed synchronously. Among all kinds of new energy vehicle technology, electric vehicle technology is the mainstream.

In China, two fields have the priority to promote electric vehicle. One is electric bus applied in public transportation, and the other is small electric car for private use. In public transportation, electric bus is easy to promote because of its nature of government service. From the view of promoting large scale production and technology testing the electric bus operating in urban transportation is best choice, The battery electric bus installed will more than 200 kWh traction battery, and its mass penetration will push industrilization of lithium traction battery. In addition, demonstration in public field leads to less minimum risk of failure and negative impression of consumer.

For private area, the electric car as new technology products, it is hard to promote. Taking technologies and industry basis into consideration, the small battery electric car is the market breakthrough products for China.

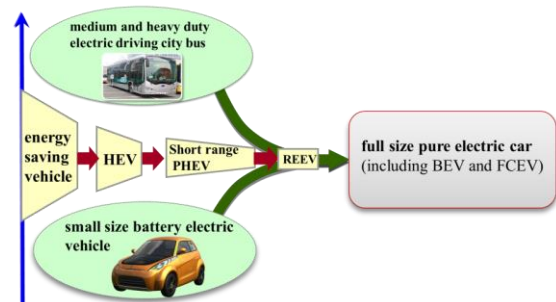


Figure 8: electric vehicle models developing strategy of breakthrough from two special points

Targeting to large scale penetration of electric vehicles, the commercial demonstration administrated by government is still very important in next few years. In the process of transportation electrification, China will experience three phases. In first stage(2006-2008), in medium and large cities of China, all kind of new energy vehicles operate in public transportation. This stage can be called testing phase. In second stage(2008-2010), called preparing for market phase, electric urban bus, hybrid electric vehicle (mainly micro/mild hybrid), small&short range electric car are products. In the third stage(2010-2015), called market introduction phase, full hybrid electric vehicles, plug-in hybrid electric vehicles and fuel cell electric vehicles technologies are all improved greatly, and demonstration vehicles operating in pilot cities are increased greatly. By 2015, all kinds of electric vehicles will account for 1% of new saling vehicles. From 2015 to 2030, it can be called market growing stage. During that stage, key electric driving components will be gradually matured and mass market of electric vehicles has formed.

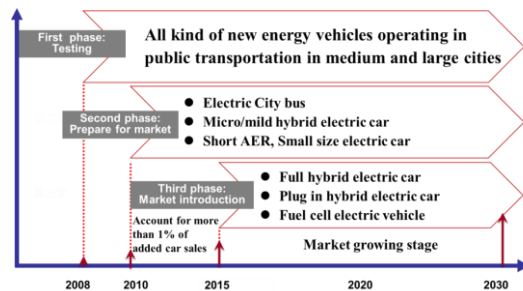


Figure 9: EVs industrialization promotion strategy of China

### 5.3 Roadmap of battery technology

Lithium iron phosphate battery will be the mainstream for China electric vehicle industry in due to its comprehensive performance. The electric driving powertrain is the focus of future sustainable transportation for China. The traction battery technology roadmap is shown as figure10. At present, the energy density is about 100Wh/kg, the 2015 target is about 150Wh/kg, and the 2020 target is about 300Wh/kg. In the large scale scenarios, the tracton battery cost will be decrease sharply, and it could be 1.5RMB/Wh, making electric vehicle more competitive in 2020[25-26].

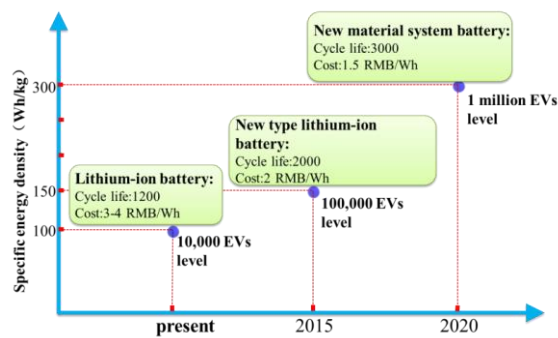


Figure 10: EVs Traction battery Technology roadmap of China

## 5.4 Outlook of electric mobility development in China

For China, in next ten years, it is a very important phase to promote electric vehicle technologies targeting to green transportation. Chinese transportation system showed obvious structure consist of 'points, lines and planar'. Big cities form points structure transportation, between large cities there presents lines structure transportation, and many small cities and towns forms planar transportation. In above mentioned transportation, there are transportation tools with China's characteristics. Inner large cities, public buses are well developed in China, especially for electric bus. At present, the population of pure electric bus operating in China has reached to 4,900, which ranks the first in the world. In many towns of China, the light electric vehicles are very popular, including electric two wheelers, electric three wheelers, low speed electric vehicles, etc. China is the biggest production and sale market of light duty electric vehicles.

The structure above mentioned

The electric transportation system above-mentioned with Chinese characteristics is the world's leading. In the future, based on this electric mobility system, point-line-panar electric transport system will be expanded.

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