Evaluation of the Plug-In Electric Vehicles Technological Roadmap in China

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Abstract
Developing electric vehicles (EVs) has been taken as state strategy from 2009. Under new EVs pushing policies, the Chinese plug-in electric vehicle market are stepping into rapid development stage from niche market to mass scale market. To summarize characteristic of plug-in electric vehicles market, evaluation the adaptability of different electric driving powertrain, and the prospect of future electric driving vehicles development based on industrialization data is very important for China to draft next 5-year plan of state EV strategy. In this research, a new kind of battery electric cars are defined as Micro-EV, which is of Chinese characteristics. Based on analysis of progress on plug-in electric vehicles, it is found that the normal battery electric car, micro-electric car, plug-in hybrid electric car and plug-in electric bus consist of the mainstream of Chinese electric driving vehicle market. China ranked first in the world at ownership of electric buses. Micro-EV will be one of most active area in next few years in cities smaller than 3-tier cities, having 50,000 annual sales potential and push development of Chinese traction battery industry. The promotion plug in electric cars for private use had made great progress, but there are still many challenges. The powertrain roadmap and architecture choice are all decisive parts of EVs’ mass market. Based on present market basis and technological advantages, the PHEV architecture of long AER (more than 50km), working as battery electric vehicles under full load condition, is suitable for China, and will be the mainstream in future.

Keywords: plug-in electric vehicles, Micro-EV, electric powertrain,

1 Introduction
The issues of energy security and urban air pollution are becoming more and more urgent for China. Since 2009, China became the biggest country of automotive production and sales. In 2014, the sales of automotive in China is increased to 22.49 million [1]. By the end of 2014, the ownership of automotive in China has increase to 154 million [2], corresponding, the dependence on crude oil being 60% [3, 4](See figure 1). Presently, the car ownership per 1000 persons is 112 (average level of world is 146), falling far behind of US and European countries of 500, so there are great potential for Chinese automotive market. In future, the rapid growth of car ownership will aggravated urban pollution,
especially for megacity as Beijing. The issues of PM2.5 emission are increasingly become severe, which has been proved very harmful to human health, however the tailpipe emission is the main resource [5], accounting for more than 30% of total. To control fog and haze weather has become the important task for local government as Beijing city.

Figure 1: automotive market and energy security

Developing electric driving vehicles has been chose as state key strategy as solution to urban air pollution by automotive. Electric driving vehicles are defined as vehicles with a bigger capacity traction battery with longer all electric range (AER), and can be charging from grid. Normally, it refers to plug in electric vehicles (PHEV) including range extended electric vehicles (REEV) and battery electric vehicles (BEV).

2 Policy and incentives

From 2009, China has issued more than 50 direct pushing policies and many aid policies. Especially from 2013, the policy and standards system is becoming more and more comprehensive, not limited to financial subsidy. Even financial subsidy approaches have been improved more reasonable from 2013. Policies of tax relief, such as travel tax and vehicle purchase tax, are important feature in 2014[6,7]. The policy of state subsidy phase out mechanism is issued in 2014[8]. It is indicated that the EVs must be developed to be more competitive from economic view to realize self-development without subsidy.

2.1 Incentives

In 2013, the second phase electric vehicle pilot program are started with new subsidy system (See figure 2).

Figure 2: the second phase subsidy for plug-in electric cars

The state subsidy for plug-in electric car is based on all electric range [9] which is different from previous subsidy system based on traction battery capacity. So it can be seen that the energy efficacy is taken into consideration in second phase subsidy system. Accordingly, many local government also respectively introduced local subsidy system according to state subsidy up to same as that, such as Beijing, Shanghai, Shenzhen, etc [10-13].

The state subsidy for plug-in electric bus is based the length also different from that of first phase subsidy system based on battery capacity (See Table 1) [9].

Table 1: State subsidy system for plug in electric buses

<table>
<thead>
<tr>
<th>Conditions</th>
<th>BEV</th>
<th>PHEV</th>
</tr>
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<tbody>
<tr>
<td>6L ≤ L &lt; 8</td>
<td>30</td>
<td>-</td>
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<tr>
<td>8L ≤ L &lt; 10</td>
<td>40</td>
<td>-</td>
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<tr>
<td>L ≥ 10</td>
<td>50</td>
<td>25</td>
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</tbody>
</table>

Where L is the length of the electric buses.

In the second phase subsidy for plug in electric bus, the length is chosen as sole criterion, and the traction battery and energy efficiency are taken into consideration, which looks not so reasonable and need to be modified.

2.2 Other pushing policies

Besides the new subsidy policy, there are many other effective pushing policies for plug-in electric vehicles, such as new energy vehicles are eligible for exempting from purchase tax, travel tax. In
some cities. Most important in some travel and purchase limited cities, such as Shanghai[11,12], free license plate for plug in electric car is more effective to improve large scale penetration of plug in electric car even than the subsidy dose. In addition, policies of subsidy for charging infrastructure, discounted pricing for electricity fee, and so on, are issued successively[14], which are all play important roles in pushing plug in electric vehicle to mass market.

3 Overall progress of PEV

Under the state policy of electric vehicles development, China are stepping from initiated market to transition period. By the end of 2014, cumulative production and sales of electric driving vehicles reached 119,000 in China, including 36,000 plug in electric buses (See figure 3) and 83,000 plug in electric cars(See figure 4,5). The ownership of new energy buses is about 60,000, ranked first in the world. In 2014, the market share in new sale bus is above 5%. Conventional hybrid electric buses have been completely replaced by plug in electric buses due to only later being eligible for state subsidy.

The ownership of electric driving cars reached 80,000, not including battery electric car installed lead acid traction battery. In 2010, annual sales of electric driving cars were only 1,000. In 2011, the number was 5000, in 2012 it was increased to 10,000, and in 2013 it reached to 15,000. In 2014, the mass market of electric cars for private use really was started to sale 55,000 plug in electric cars. It is indicated that China has stepped in to rapid growth period.

4 Annual characteristics analysis

The plug in electric vehicles market of China is stepping into rapid development phase. In 2014, the annual production reached to 84,900, including 13,300 plug-in hybrid electric buses, 12,700 battery electric buses, 16,600 plug in hybrid electric cars, 38900 battery electric cars and 3,400 electric special vehicles. The annual production proximate to sales number of plug in electric bus is about 26,000 accounting for 5.0% market share in new sales of buses market, which falls ahead of other countries a lot. The annual sales of plug in electric cars in China ranked second in the world following US, whose annual sales of plug in electric car is close to 120,000. The annual sales of PEVs China overtakes that of Japan first time. If the market of plug-in electric vehicles could be split into four sectors, including Mico-EV, Plug-in hybrid electric car, battery electric car and plug in electric bus(including battery electric bus and plug-in hybrid electric bus). By analysis of statistical data, it can been conclude that (See Figure5).
4.1 Plug in electric bus

In electric bus field, China is competitive not only in market but key technologies, and many innovative technological solutions were tried. Various energy storage system all adopted in the electric buses in China, including super capacitor, lithium ion traction battery (LFP, NCM NCA), Titanate battery (Li4Ti5O12, referred to as LTO in the battery industry), super capacitor plus lithium ion traction battery, etc. Presently, there are various powertrain schemes, including compound hybrid to direct driving wheels with dual electric motors, parallel configuration and range extended in serials connection from powertrain architecture view.

There are also different kinds of electric buses solutions from methods of energy storage device assembly. The battery electric from BYD is designed with large traction battery capacity to realize long range, more than 200km. HengTong Bus Company applied LTO battery electric buses to meet requirement of high current charging up to 10 C\footnote{\cite{15}} with limited driving range (about 50km) due to its low energy density of LTO. The battery swapping mode also exist in electric bus, mainly operated by Sate Grid, for example battery electric bus operating in Qingdao, Tianjin. Other typical charging mode for electric buses is online charging. This kind of electric buses are operating in Zhuzhou city based on previous power lines.

4.2 Plug in electric cars

Judging from the total amount of the analysis present plug in electric market and the market potential, the plug in electric cars have been the mainstream. The market of plug in electric cars is compose of 2 kinds of powertrain, including conventional battery electric cars, plug in hybrid electric cars and Micro-EV\footnote{See figure 6}.

There are peak values in July, September and December. In July, the local subsidy schemes are issued concentrated. In September, the policy of new energy vehicle exempting purchasing tax implemented. In December, to achieve demonstration objective, some pilot city rushed to complete tasks, on the other hand, next year, the subsidy will be phase out 10%, so at the end of 2014, it is the purchasing peak period.

All indicated that new energy cars market of China is very sensitive to policy. China are in a sensitive period of transition, so continuity of policy is very important.

4.2.1 Conventional battery electric cars

The sales of normal size battery electric cars are increased by twice. Due to the insufficient charging infrastructure and the limitation of traction battery production capacity, the industrialization battery electric cars was restricted greatly compared to plug in electric cars. Only the annual sales of 3 models exceed 1,000, and they are SAIC E150, BYD e6 and JAC iEV4. The sales of BAIC E150 battery electric car surged to 5,000 annually, and highest single –month sales exceeded 1,700.

<table>
<thead>
<tr>
<th>Table 2: Parameters of E150</th>
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<tr>
<td>items</td>
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<tr>
<td>Curb mass, kg</td>
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<tr>
<td>Top speed, km/h</td>
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<tr>
<td>Battery capacity, kWh</td>
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<tr>
<td>0-100km/h acceleration time, s</td>
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<tr>
<td>AER(NEDC), km</td>
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</table>

E30 battery electric car from Dongfeng-Nissian, which is same as Leaf battery electric car, is introduced just at the end of 2014, so the sales is
not high and maybe have great market potential next year.

4.2.2 Plug in hybrid electric cars
The models of plug in electric car are fewer than that of battery electric car, and only two models in sale, including BYD Qin and SAIC ROEWE 550PHEV. The high annual sales record is created by BYD Qin with 15,000. The parameters and performance of Qin is shown as Table 2. In research of Tsinghua University on PHEV configuration technologies, it is be defined the PHEV types could be divided into two, and they are HEV-type PHEV or called energy-saving PHEV and RE-PHEV (range extended PHEV) or called BEV-type PHEV. The evolution rout of PHEV powertrain is shown in figure 8.

<table>
<thead>
<tr>
<th>items</th>
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<tr>
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<tr>
<td>Battery capacity, kWh</td>
<td>13</td>
</tr>
<tr>
<td>0-100km/h acceleration time, s</td>
<td>5.9</td>
</tr>
<tr>
<td>AER(NEDC), km</td>
<td>70</td>
</tr>
<tr>
<td>Electricity consumption, kWh/100km</td>
<td>16.5</td>
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<tr>
<td>Fuel economy(NEDC),L/100km</td>
<td>6.2</td>
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![Figure 8: Evolution rout of PHEV powertrain](image)

It can be seen that BYD Qin PHEV is a typical BEV-type PHEV, of which AER is more than 50km and battery capacity installed is more than 10kWh. Under urban condition, the PHEV only work as BEV, engine not working to realize no local emission.

This kind of PHEV technology is suitable to Chinese market by the market data analysis. In 2014, the average monthly sales are about 1,300(See Figure 9). Actually the market demand is about 4,000 in China.

![Figure 9: BYD Qin PHEV sales in 2014](image)

More than 80% are sold in Shenzhen and Shanghai(See figure 10). The lowest retail price of Qin is 188,400. In 2014, it can obtain 32,500 state subsidy, and same amount of local subsidy in some cities, such as Beijing, Shanghai, Shenzhen, etc. So the plug in hybrid electric cars as BYD Qin is eligible to get 65,000 RMB subsidy all together. In some districts of Shanghai, it can also get additional subsidy from 10,000 to 20,000, such as Pudong district, Minxing district and Jiading district.

![Figure 10: Regions for sale of Qin](image)

Based on statistic data and survey results, it is predicted that after April 2015, sales of plug in hybrid cars will be significant growth. The total annual sales of plug in hybrid electric cars may create new record to become the second big PHEV market in the world after U.S. In 2015, BYD is expected to be the most popular PHEV in the world judged by sale data.
4.2.3 Micro-EV

In this research, Micro-EV are defined as the battery electric cars that with the characteristics as following:

(1) Small size: the length is no more than 3500mm, the seats is no more than 4; the curb weight is no more than 800kg(if AER ≤80).

(2) Low price: MSRP is no more than 55,000RMB(deducted state and local subsidies)

One most notable phenomenon of Chinese plug in electric cars in 2014 is the rapid growth of Micro-EV. The manufacture of previous low-speed electric vehicles obtained legal qualification by joint venture with conventional automotive OEM to introduce own newly designed Micro-EV, such as Hangzhou Kangdi with Greeley, XINDayang with Greely and Shikong with Zotye. Based on above joint venture relationship, annual sales of 2 seats and 4 seats Micro-EV from Kangdi reached to 13,000. The total annual sales of Micro-EV are added up to 23,000, including 5 models from Kangdi, XinDayang, Shikong, Zoety and Cherry. Among the total Micro-EV, there are more than 70% for leasing.

Table 2: Parameters of Kangdi K10 Micro-EV

<table>
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<th>values</th>
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<tbody>
<tr>
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</tr>
<tr>
<td>Top speed, km/h</td>
<td>80</td>
</tr>
<tr>
<td>Battery capacity, kWh</td>
<td>10</td>
</tr>
<tr>
<td>0-50km/h acceleration time, s</td>
<td>10</td>
</tr>
<tr>
<td>AER(NEDC), km</td>
<td>150</td>
</tr>
</tbody>
</table>

In terms of the performance the above mentioned Micro-EV models are similar, such as top speed is 80km/h, AER is 150km, and accelerating time from 0 to 50km/h is about 10s.

In future, there will more manufactures as Kangdi, to cooperate with automotive OEM, so the market of Micro-EV will have tremendous growth if no new restrictions are issued. In 2014, the annual sales of low-speed electric vehicles reached to 400,000. So if 10% of low speed electric vehicles could be transferred to Micro-EV introduced into market, the potential would be no less the 50,000 annually.

This kind of battery electric cars are mainly introduced in 3-tier, 4-tier cities and countryside, etc, not like the PHEVs which are generally for any private use.

5 Conclusion and discussion

From the analysis above mentioned, it can been concluded that China has stepped into rapid development stage of plug in electric vehicle, especially for plug in electric cars for private application following

(1) There are four electric powertrain roadmap consist of the plug in electric vehicles market, electric bus, conventional battery electric cars, plug in hybrid electric car and Micro-EV. Market of electric buses will be stable and increased gradually to replace ICE buses. Micro-EV and plug in hybrid electric cars will have significant growth potential. The former need to draft new regulation to standardize development, and the later need to be improve the key technologies and energy consumption testing and evaluation standards.

(2) The plug-in electric cars market of China is in the stage from cultivation stage to development stage, and it is very sensitive to policy, so the state subsidy should not phase out too fast and too early to crash the mass market initially established.

(3) Plug in hybrid electric car will be the most potential powertrain roadmap for China in private field next 5 years. Choice of PHEV architectures is very important to adapt to Chinese market to take advantage of the industry and technologies basis. The RE-PHEV should be mainstream roadmap of China.

(4) Traction battery production capacity limitation is still important bottleneck for EVS mass market.

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References


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