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A Summary of the Chinese New Energy Vehicles' Development during the 12th Five-Year Plan Period and a Prospect for the 13th Five-Year Plan Period

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Abstract: To better support further decisions in China's new energy vehicles industry, and to promote the rapid and healthy development of this industry, our research group has fully researched the development situation of the domestic new energy vehicles industry and summarized the achievements of China's 12th Five-Year Plan. We have performed a systematic analysis of the impact and effectiveness of the demonstration project and the technology innovation project, and have further evaluated the maturity level of the technology, manufacturing, and market. Finally, we have made a prediction on the 13th Five-Year Plan based on the latest developments and rules.
Key words: new energy vehicles industry; summary; typical cases; situation prediction; suggestion

1. Introduction

It is of great strategic significance for China to vigorously develop energy-saving and new energy vehicles; to develop a circular economy and economic strategy; to practice supply-side structural reform; to promote the transformation and upgrading of the vehicle industry; to enhance the international competitiveness of industries; and to build an environmentally friendly society [1]. In this paper, we comprehensively summarize the main achievements of China's new energy vehicles industry during the 12th Five-Year Plan period in terms of policy, market, products, technology, infrastructure, and maturity. We also make a prediction regarding China's new energy vehicles industry during the 13th Five-Year Plan period, based on the latest developments and rules.

2. Overall progress of the new energy vehicles industry during the 12th Five-Year Plan period

China's new energy vehicles industry is an important part of the national implementation of an energy strategy adjustment and of the transformation and upgrading of the vehicle industry. During the 12th Five-Year Plan period, with the cooperation of all sectors of industry, our new energy vehicles industry has achieved significant improvements in policy system, market size, product technology, infrastructure, and other aspects.

2.1. Policy support

In 2010, China's new energy vehicles were listed as one of the seven new strategic industries. In 2012, the State Council issued the *Energy-Saving and New Energy Vehicles Industry Development Plan (2012–2020)*, and the strategic orientation of this industry gradually became clear. In addition, the industry support policy system was gradually improved. More than 7 billion yuan was invested as a research and development (R&D) special fund, which led to tens of billions of yuan being invested during the 12th Five-Year Plan period. In terms of demonstration and promotion, the buying, using, and charging infrastructures, along

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with other aspects for the new energy vehicles, gradually formed a diversified support policy, in which financial subsidies and tax incentives occupied the main position, with non-fiscal policy as an important supplement. Regarding standardization, 75 electric vehicle standards were issued [2], including basic general, vehicle, key assembly, interface, electric accessories, and infrastructure standards. In addition, a special management policy for the new energy industry was created, and the approval/filing of investment projects and the admission notice management of enterprises and products are now strictly ruled. Industry management is gradually becoming standardized, and enterprises are being encouraged to improve.

2.2. Market size

Driven by policy, the market size of China's new energy vehicles is increasing. In 2015, production of the new energy vehicles surged 380% from one year to the next, up to 379 000 vehicles, and sales surged 340%, up to 331 100 vehicles. Meanwhile, China surpassed the United States to rank as the top worldwide producer of new energy vehicles [3]. By the end of 2015, the cumulative number of new energy vehicles produced was 450 000, thus basically achieving the goal of 500 000 vehicles set out by the *Energy-Saving and New Energy Vehicles Industry Development Plan (2012–2020)*, and accounting for 1% of the entire vehicle market. Clearly, China's new energy vehicles industry is about to enter a new stage of rapid development.

2.3. Product technology

The levels of China's new energy vehicles and their autonomous technology have been improving. A system of a three-platform "three vertical and three horizontal" type of matrix has essentially been accomplished. First, the oil consumption per hundred kilometers of plug-in hybrid electric vehicle (PHEV) passenger cars has decreased to less than 2 L. Second, the driving range of the electric vehicle (EV) now exceeds 400 km. Third, technical indicators such as 0–100 km acceleration capability and power consumption have increased significantly, and performance indicators of the mid-size and smaller vehicle models are close to the international standard. Fourth, the performance of the new energy bus is at an internationally leading level, with China's new energy buses being exported to the UK, Brazil, and many other countries. Fifth, fuel cell vehicles have been trial-produced. In addition, the energy density of the single lithium-ion battery is 200 $(W \cdot h) \cdot kg^{-1}$, the efficiency density of the driving motor is 2.8–3.0 $kW \cdot kg^{-1}$, and the maximum efficiency of the driving motor is more than 94%.

2.4. Infrastructure

Since China's 12th Five-Year Plan, the construction speed of charging facilities has been accelerating, and the vitality of the industry has been strengthening. As a result, an initial urban and intercity charging network has been constructed. By the end of 2015, 3 600 charging stations and 49 000 public charging posts were constructed, significantly improving the charging application environment [4]. As new charging models continue to appear, such as crowd funding charging, the public-private partnership (PPP) model, and public facilities charging, different fields and different types of charging needs are met. Meanwhile, investments are improving, and the commercial pace is accelerating.

3. A typical case during the 12th Five-Year Plan period: The demonstration and promotion project

Since 2009, China has implemented several demonstration and promotion projects, such as "ten cities and each city of 1 000", "the work that expands promotion of the hybrid bus" and "the work that continues to promote the use of new energy vehicles". Due to these projects, the cumulative number of promoted vehicles is more than 416 000, indicating that the markets of both the public and private fields have been opened. These projects played a guiding role in the early stages of industrial development (Fig. 1).

3.1. The scale of promotion grew rapidly, and market cultivation took effect

The "ten cities and each city of 1 000" project marked the start of the demonstration and promotion projects for China's new energy vehicles. By the end of 2012, 27 432 new energy vehicles had been promoted in 25 demonstration cities, of which

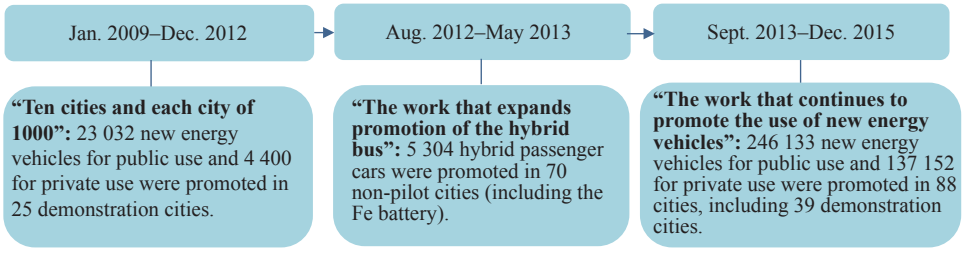

Fig. 1. The demonstration and promotion of China's new energy vehicles from 2009 to 2015.

23 032 vehicles were for public use, accounting for 84 % of the total. From January to May of 2013, all of China's ministries and commissions implemented "the work that expands promotion of the hybrid bus" in non-pilot cities. A total of 5304 hybrid buses were promoted by centralized bidding, speeding up the process of marketization. In September 2013, a new demonstration and promotion project made the new energy vehicles available for private use. By the end of 2015, more than 383 000 new energy vehicles had been promoted in 39 demonstration cities, of which more than 137 000 vehicles were for private use. The typical scale of expansion is exemplified by Shanghai, Shenzhen, and Beijing, where there are more than 30 000 new energy vehicles in private use.

3.2. With the advent of advanced business model, consumption potential was excited

While the scale of promotion grew rapidly, there were many typical business models developed by different demonstration cities and by automakers. For public transportation system, business models for financial leasing, battery leasing, and a combination of charging and maintenance were developed. For taxi passenger transportation system, business models that each taxi driver took full contract responsibility to run 24 hours a day and get the fixed revenue are developed. In vehicle leasing area, the mini-bus models that some vehicle manufacturers seek to replace vehicle selling with vehicle leasing and adopt the models of time-sharing and installment leasing were developed. In terms of logistics, business models of it were operating by specializing companies, vehicle leasing, and a combination of maintenance and repair. A directional purchase business model was also developed for the private use of vehicles. In addition, since 2013, more than 16 000 KANDI battery electric vehicles have been serviced in Hangzhou, and KANDI's Car2Go model is being promoted in Shanghai, Suzhou, and other cities.

3.3. Automobile and parts enterprises developed in tandem, and the industrial chain expanded

Owing to the demonstration and promotion projects, automobile and parts enterprises developed in tandem, and the industrial chain expanded. As of December 2015, a total of 3 304 models from 275 vehicle enterprises have been registered in the official announcements of vehicle manufacturers and products; these include 123 passenger vehicle enterprises, 96 bus enterprises, and 56 special-purpose motor vehicle enterprises. In addition, there were more than 200 power battery enterprises in China as of 2015, and these can produce nearly 40 billion W·h energy per year. Since automobile and parts enterprises developed in tandem, the upstream and downstream regions of the industrial chain can draw on each other's comparative advantages in order to achieve mutual benefits and realize deeper development together. Fig. 2 shows the relationships between enterprises producing whole vehicles and those producing parts of vehicles in China's new energy vehicles industry.

4. A typical case during the 12th Five-Year Plan period: The technological innovation project

Approved by the State Council, the Ministry of Finance (MOF), the Ministry of Industry and Information Technology (MIIT), and the Ministry of Science and Technology (MOST) organized the implementation of the "technological innovation project of China's new energy vehicles" in 2012. This initiative supported 25 projects, including the latest designs for the new energy vehicle and power battery. Since the implementation of

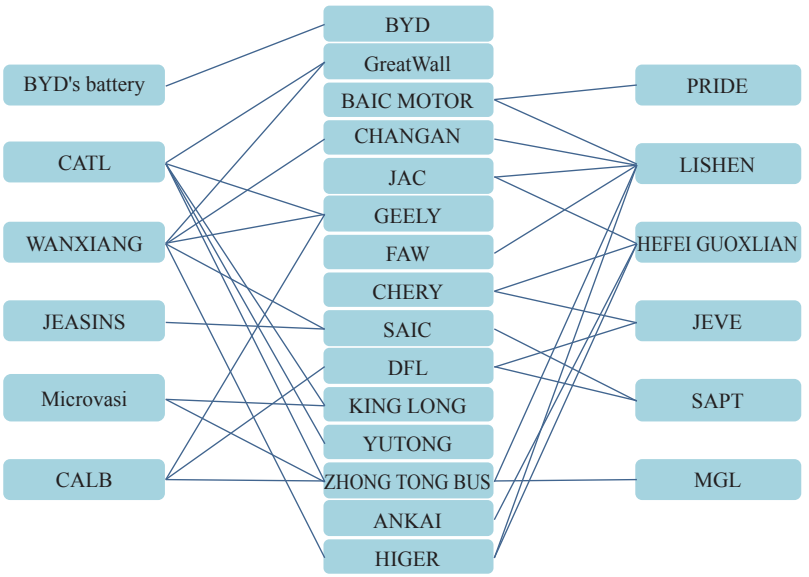

Fig. 2. Relationships between enterprises producing whole vehicles and those producing parts of vehicles in China's new energy vehicles industry.

these projects, the overall technical level of China's new energy vehicles has improved, and the core competence of the industry has been strengthened.

4.1. The overall technical level of the new energy vehicles improved, reaching an international level

Remarkable achievements were made in the PHEV projects, and the comprehensive performance of China's PHEVs reached the international advanced level. The maximum speed of BYD's Qin and of SAIC's Rongwei 550 is more than 180 km·h^{-1}, and their comprehensive oil consumption is less than 2.0 L per hundred kilometers. In other words, their comprehensive performance is at or above the level of world-famous vehicles such as Volt and Prius (Table 1) [5]. The fuel-saving ratio of the PHEV is 70%, and the oil consumption of Yutong's typical 12 m hybrid model is 18.9 L per hundred kilometers, as tested by third parties; this model is superior to general domestic and foreign products. Table 2 shows a comparison of the oil consumption of PHEV hybrid models.

Projects involving the battery electric vehicle (BEV) and vehicle batteries make remarkable achievements, with some of the technical indicators reaching the international advanced level. The distance per charge of a BEV such as a passenger vehicle can be greater than 250 km and the maximum speed is greater than 150 km·h^{-1}; according to the Economic Commission for Europe (ECE) and the Extra Urban Driving Cycle (EUDC), the comprehensive electricity consumption per hundred kilometers is less than 12 kW·h. In addition, indicators of acceleration performance and energy consumption level are also raised. The energy density of a single lithium-ion battery is more than 200 (W·h)·kg^{-1}, reaching the international advanced level. Enterprises such as Contemporary Amperex Technology Ltd. (CATL), which produces lithium-ion batteries units, have become the world's leading new energy vehicles parts suppliers. Fig. 3 shows the single-body energy density of various power batteries.

4.2. Technological innovation and market promotion occurred, with rapid growth in market size

Through the support and cultivation of technological innovation project, the new energy automotive market process continues to accelerate, and international awareness of the products of China's star enterprises is also rising. By the end of 2015, out of the innovative projects on the market, more than 102 vehicle products and 16 power battery products entered the main market, with this proportion gradually expanding. In 2015, BYD Company Ltd., KANDI Electric Vehicle Group, Zotye Holding Group, and other enterprises entered the top ten for global annual sales of new energy vehicles, with BYD ranking first in the world. Yutong's new energy buses were sold in more than 30 countries around the world, greatly enhancing China's international brand image. CATL's power battery products have accumulated more than 2400 units (with a target of 1000 units) and the enterprise is successfully matching BMW and other well-known foreign enterprises.

4.3. Enterprises are encouraged to increase R&D investment and form independent intellectual property rights

The technological innovation project also reflects the leverag-

Table 1. Comparison of comprehensive performance of PHEVs.

Parameter	Domestic		Overseas			
	BYD's Qin	Rongwei 550 PLUG-IN	Prius PHEV	Volvo S60L	BMW 530Le	Outlander PHEV
Time to market (year)	2014	2015	2013	2015	2015	2014
Wheelbase (mm)	2 670	2 705	2 700	2 856	3 180	2 670
Curb weight (kg)	1 720	1 699	1 395	1 996	–	1 810
Max speed (km·h^{-1})	185	203	180	210	233	170
0–100 acceleration time (s)	5.9	10.5	10.7	5.5	7.1	11
Pure electric range (km)	70	58	23.4	53	58	52
Comprehensive oil consumption (L·(100 km)$^{-1}$)	1.6	1.6	2.6	2.1	2	1.9

Table 2. Comparison of the oil consumption of PHEV hybrid models.

Dynamical system and oil consumption	YUTONG	Domestic enterprise 1	Domestic enterprise 2	Domestic enterprise 3	Domestic enterprise 4	Domestic enterprise 5
Dynamical system	Coaxial compound system	SONGZHENG fourth-generation double motor AMT	Double motor direct drive system	EATON AMT	Double motor AMT	AMT
Oil consumption (L·(100 km)$^{-1}$)	18.90	24.80	26.00	23.40	19.71	26.00

Date source: Based on test results according to GB/T 19754—2005 and enterprises' promotional materials.

ing effect of R&D incentive funds. Statistics show that the state planned to invest 4 billion yuan during this period, a sum that actually drove enterprise R&D investment to reach 15.7 billion yuan (Fig. 4). Enterprises were promoted to master independent intellectual property rights. Applications were made (including licenses) for more than 1 500 patents and more than 600 patents were invented (Fig. 5).

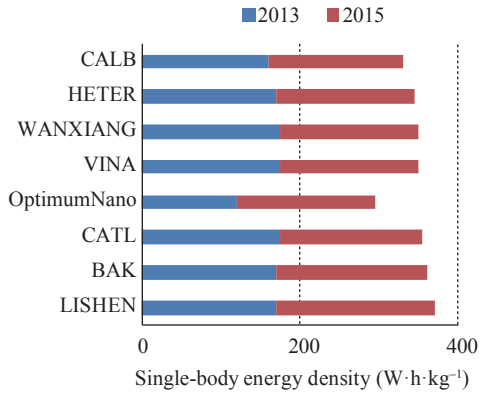

Fig. 3. The single-body energy density of various power batteries.

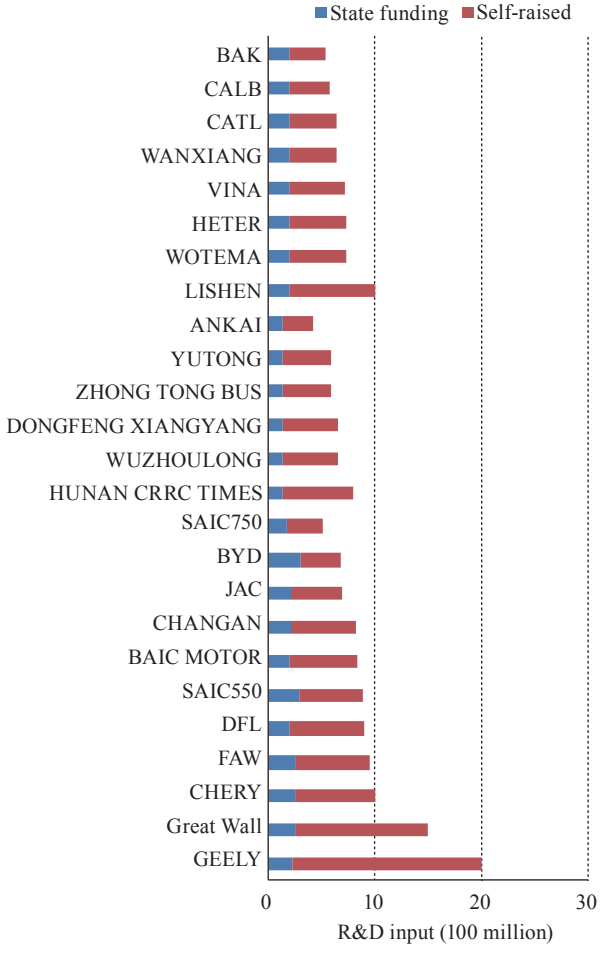

Fig. 4. Investment ratio of innovation projects.

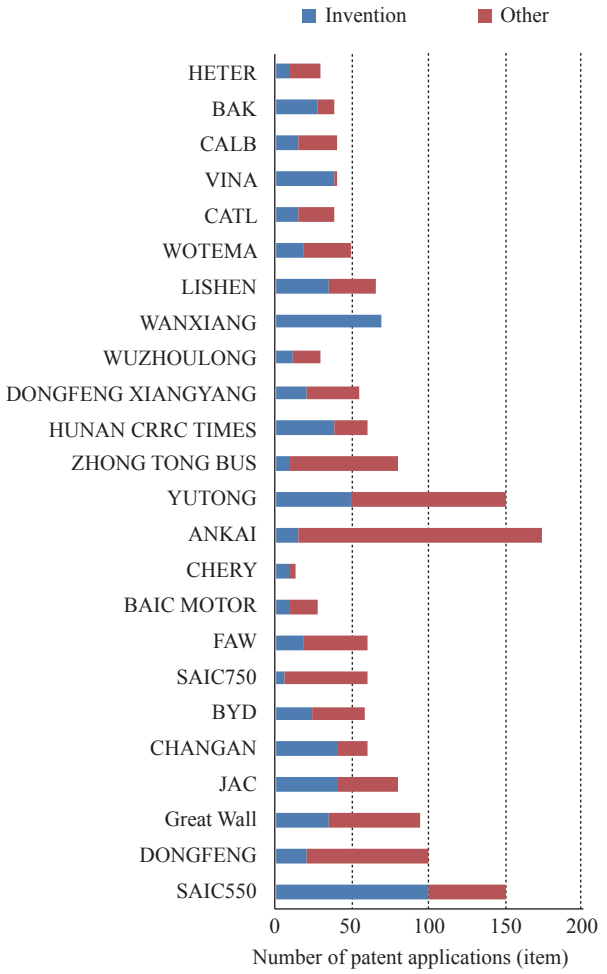

Fig. 5. New applications or licensing for new energy vehicles patents.

5. Maturity evaluation

After the national “863” plan, the promotion of demonstration projects, technological innovation projects, and other major projects continues. To a certain degree, an industrial base has been established for China’s new energy vehicles, and the market attention received by these products is growing. The industrial maturity of different technical routes is also increasing. This so-called industrial maturity refers to the development stage of the industry (i.e., embryonic, nurturing, development, or mature stage). Industry maturity evaluation method is a combination of qualitative and quantitative methods that characterize the development and maturity of the industry by conducting different stages of evaluation on the technology, manufacturing, product, and market [6]. Based on the industrial maturity evaluation method of the China Aerospace Engineering Science and Technology Development Strategy Research Institute, we have analyzed the current situation of China’s new energy automotive industry. Here, we finally come to the key area of maturity evaluation results.

Specifically, industrial maturity is assessed in terms of product maturity and market maturity. As mentioned earlier, indus-

trial maturity has four stages: the embryonic stage, nurturing stage, development stage, and mature stage. Product maturity is composed of technology maturity and manufacturing maturity, and involves five stages—from the concept of products to lean market products. Technology maturity, measured by technology readiness levels (TRLs), is divided into nine levels—Starting from the discovery of the basic principles, moving through the concept of the technology and the assumption of its application, and ending with the development of mature technological products from the whole process. Manufacturing maturity, measured by manufacturing readiness levels (MRLs), is used to show the maturity of a key manufacturing capability. It quantifies the degree of satisfaction in the manufacturing capability to meet target requirements. Manufacturing maturity is divided into ten levels that cover the whole process from proposing the concept of manufacturing to the formation of full-rate production and lean production capacity. Market maturity levels (MMLs) refer to an evaluation and measurement of the market relative to its full maturity (i.e., import, growing, and maturity stages). Market maturity evaluates three aspects: market size, market structure, and market potential.

5.1. Hybrid EVs (including plug-ins and added mileage)

Based on a combination of the product and market maturity evaluation results, China's hybrid car industry is still at a maturity level of IML2; that is, it is in the nurturing stage.

5.1.1. Product maturity level is PRL4—Market products

Vehicle manufacturers in China are exploring hybrid vehicle technologies with a multi-technical-routes mechanism. Different types of hybrid passenger vehicles have been developed by their serialized platforms. The integrated fuel consumption of the new hybrid cars has reached 2 L per hundred kilometers, which gives them a certain advantage. The oil-saving rate of hybrid car model B can reach 35%, demonstrating an obvious fuel-saving effect. However, the common key technologies of the hybrid EV in China and the reliability and stability of these products still need further enhancement. The level of wide application and testing has not yet been achieved. Hybrid vehicles in China are at the stage where trial vehicle models are able to pass tests and are ready for delivery experiments; in other words, the technology maturity is 8. At present, China has the ability to develop all kinds of hybrid EVs with independent intellectual property rights, and has established a new power system and auxiliary system, as well as other key assembly production systems and a quality control system. The manufacturing process in China has matured. However, engineering development is relatively weak and needs further strengthening. A low-rate production capacity has been verified and we are preparing to start full-rate production. Therefore, the manufacturing maturity of the industry is MRL9. Table 3 provides an analysis of the maturity of hybrid electric power (including plug-ins and added mileage) in China.

Table 3. Analysis of the maturity of hybrid electric power (including plug-ins and added mileage) in China.

Product maturity	Market maturity		Industry maturity
PRL 1 □	—	IML 1 □	Embryonic stage
PRL 2 □			
PRL 3 □			
PRL 4 √	MML1 √	IML 2 √	Nurturing stage
PRL 5 □	MML2 □	IML 3 □	Development stage
	MML3 □	IML 4 □	Mature stage

5.1.2. Market maturity level is MML1—Large upfront investment, low market revenue stage

By the end of 2015, China had promoted 96 794 PHEVs in 39 demonstration cities, including 71 207 plug-in hybrid passenger cars and 25 587 plug-in hybrid electric buses. The competitive power of the hybrid vehicle, as compared with the traditional car, is gradually being revealed, and its market share is growing very rapidly. However, production and sale are concentrated in only a small number of enterprises, and high technical barriers exist. After deducting their subsidies, companies are not yet profitable.

5.2. Battery electric vehicles

Based on a combination of the product and market maturity evaluation results, China's pure EV industry maturity level is IML2; that is, it is in the nurturing stage.

5.2.1. Product maturity level is PRL4—Market products

Regarding technical maturity, domestic pure EV battery technology is improving and accelerating. Bulk production of lithium-ion power battery energy density is up to 200 $(W{\cdot}h){\cdot}kg^{-1}$, and the vehicle driving range of the general product is up to 200 km or more, such that it can meet the basic requirements of short-range use. The power consumption of pure electric passenger cars per hundred kilometers averages 15–18 kW·h, and the power consumption of the pure electric bus per hundred kilometers averages 50–100 kW·h. However, there is a certain bottleneck in power battery technology. The battery attenuation phenomenon is obvious, and the battery cycle life is significantly lower than the experimental test level. We need to strengthen technical R&D breakthroughs for China's pure EV technology in order to achieve a mature product level, as evaluated by a wide range of applications and tests. The current technology maturity for pure EVs industry is TRL8.

Regarding manufacturing maturity, by relying on the development of traditional automobile enterprise groups, China

has already formed a pure EV industry base that currently has mass-production capacity. By the end of 2015, the number of pure EVs listed on the market reached 2 593, including 266 passenger cars, 1 582 buses, and 745 special vehicles. The product category is relatively abundant. However, vehicle integration, battery technology, and other technologies have yet to be improved. For China's pure EVs, the stage at which full-rate production capacity has been verified and lean production exists has not yet been reached. Rather, China's pure EVs are at the level where low-rate production capacity has been verified, and full-rate production is ready to begin. The manufacturing maturity level of pure EVs industry is MRL9. Table 4 provides an analysis of industrial maturity for pure EVs.

Table 4. Analysis of pure EV industrial maturity.

Product maturity	Market maturity		Industrial maturity
PRL 1 □			
PRL 2 □	—	IML 1 □	Embryonic stage
PRL 3 □			
PRL 4 √	MML1 □	IML 2 √	Nurturing stage
PRL 5 □	MML2 √	IML 3 □	Development stage
	MML3 □	IML 4 □	Mature stage

5.2.2. Market maturity level—Basically MML2

Through the promotion of the project, pure EVs have achieved a considerable amount of operation in official, rental, public transport, private, and other areas. The number of pure EV enterprises and products has increased significantly. From 2013–2015, China's 39 demonstration cities have been promoting 280 000 pure EVs. In 2015, domestic pure EV sales reached 255 000, which was a high global level. However, because the current power battery energy density is still less than that of fossil fuels, and also because of inadequate charging facilities and high prices, it is still difficult for pure EV companies to profit after deducting their subsidies. Challenges remain regarding the entrance of pure EVs into the market.

6. The 13th Five-Year Plan outlook

In the first half of 2016, the state implemented supervision to promote the application of field inspection for the new energy vehicles. It also implemented more stringent assessment criteria for applications from power battery enterprises, started the 13th Five-Year Plan new energy vehicle pilot special declaration, and established a national power battery innovation center and other major initiatives. The state moved forward to improve the vehicle enterprises' access threshold and issue a carbon quota subsidy policy in the next stage of planning, as it tried to guide the industry to continue with healthy, standardized, and sustainable development. Under the guidance of national policy, combined with the law of market development, China's new energy vehicles industry will grow, with more attention being paid to quality improvement, in order to achieve a major breakthrough in the market, product technology, infrastructure, and more during the 13th Five-Year Plan period.

6.1. Shifting from government-led to market driven, with continuous upgrading of the industrial scale

During the 13th Five-Year Plan period, China's new energy vehicles industry will gradually become mature. Product subsidies and other preferential policies will gradually fall off. Market leadership will be transferred from the government to the social consumer. In this context, concerned enterprises will further increase their R&D efforts in order to improve the competitiveness of the product market and thus continue to promote the rapid development of the new energy vehicles industry. Based on the macro trend, combined with the production and marketing situation over the past three years, the production and marketing scale of China's new energy vehicles in the second half of 2016 will be far greater than that in the first half of the year. It is expected that in the second half of 2016, production will be three times greater than that in the first half of the year, reaching 600 000–500 000, while the annual total output of new energy vehicles will reach 600 000–700 000. In 2017, new energy vehicles sales are expected to exceed 1 million over the full year.

6.2. Business strategy is clear and integration with new capitals is accelerating

Based on enterprise public information statistics, during the 13th Five-Year Plan, domestic and foreign mainstream vehicle enterprises will invest hundreds of billions in funds into the field of energy-saving and new energy vehicles, and will work on the development of more than 200 new energy vehicles [7]. Related moves show that the major car companies regard energy-saving and new energy vehicles as future market heights, and are making them the focus of their layouts (See Table 5).

From the perspective of competition, in the future, there will be three influences wrestling in the market: traditional vehicle manufacturers, new-entering capital, and foreign capital. Representative new-entering capital, such as NEXTEV, Tencent, and Foxconn Technology Group, entered the market through alliance and mergers and acquisitions (M&A) strategies. For example, Tencent and Foxconn Technology Group have teamed up with China Harmony Auto Holding Ltd. to develop luxury pure EVs, while NEXTEV and JAC have comprehensively cooperated in the field of EVs. The accelerating entry of newcomers shows that the future of new energy vehicles is widely accpeted by different fields, and also shows that the market will usher in more intense competition.

Table 5. Domestic passenger car business in the 13th Five-Year Plan period: Strategic planning for energy-saving and new energy vehicles.

Enterprise	Investment/Business	Target	New energy vehicle planning
BAIC Motor Co., Ltd.	Revenue of 60 billion yuan	Annual sales volume of 500 000 vehicles	11 new cars
SAIC Motor Co., Ltd.	Investment of over 20 billion yuan	Annual sales volume of 200 000 vehicles	More than 30 new cars
FAW Group	—	Account for more than 15% of market share	16 models in the full range of industrial preparation
BYD Co., Ltd.	Fundraising 15 billion yuan	Production capacity of 2 million vehicles, cumulative production and sale of 5 million vehicles	"7+4" strategic layout
Changan Automobile Co., Ltd.	Total investment of 18 billion yuan	Cumulative sales of 400 000 vehicles in 2020	27 pure electric vehicles, 7 plug-in hybrid power
Guangzhou Automobile Co., Group Ltd.(GAC)	2 billion yuan	Annual sales volume of 100 000 vehicles	6 new models
Jianghuai Automobile Co., Ltd.(JAC)	Fundraising 4.5 billion yuan	New energy vehicles will account for more than 30%	7 cars before 2017
Chery Automobile Co., Ltd.	Investment of 1.56 billion yuan	Annual sales of 200 000 vehicles	Class A plug-in hybrid power, A0/A00-EV+REV(add mileage electric car)
Geely Holding Group	Investment of 10 billion yuan	Plug-in hybrid/hybrid vehicles will account for 65% and Pure electric vehicles will account for 35%	Plug-in hybrid power system, HV equipped with A/class A
LIFAN Group	Fundraising 5.2 billion yuan	Total sales of new energy vehicles will reach 500 000	21 EVs and hybrid power new products
Great Wall Motor Co., Ltd.	Fundraising 16.8 billion yuan	—	Car: Electric car or 48V, SUV: Plug-in hybrid power
Jiangling Motors Co., Ltd.	Investment of 180 million yuan	Annual sales volume of 70 000 vehicles	4 new cars
Haima Automobile Group Co., Ltd.	—	New energy vehicles sales will account for 20% of total sales	6 new cars
Zotye Holding Group	Total investment of 10 billion yuan	—	12 new cars

6.3. Products continue to be broken through; differentiation development of technical routes at home and abroad

Due to the strong implementation of *Made in China 2025* and enterprises' corporate R&D drive, China's new energy vehicles will make breakthroughs in product technology. During the 13th Five-Year Plan, the distance per charge of pure electric passenger cars is expected to increase to well over 300 km. Attempts will be made to introduce the fuel cell buses into industrial applications. The lithium-ion battery module is expected to exceed an energy density of 300 $(W \cdot h) \cdot kg^{-1}$. High-voltage electrolytes and other battery-based materials have been successfully developed. The motor at 15 000 $r \cdot min^{-1}$ or above will enter the stage of mass production.

The technology route for the new energy vehicles carries the tendencies of diversified development. In the near future, foreign-invested vehicle model will be based on plug-in hybrids and hybrids. Independent vehicle model will be based on EVs and plug-in hybrids. EVs are mainly used in the compact and smaller-sized car market. New energy vehicles that are bigger than compact-sized vehicles are mainly PHEVs. Only a few enterprises, such as BYD and BAIC Motor, have developed a pure EVs plan for the intermediate level and above [8].

6.4. Infrastructure development in speed, and synchronous innovation of the construction and operation modes

At present, the proportion of new energy vehicles to charging piles in China is about 4:1. The number of charging piles is still insufficient. This imbalance will constrain the size of the new energy vehiches industry [9]. As a result, the state and local governments will continue to increase support for the construction of infrastructure, and will encourage innovation in construction and operation modes.

Social capital will enter the arena of construction, and the crowd funding pile construction model will be rapidly developed. The number of charging piles is expected to quickly pass 200 000. Wireless charging is expected to intervene in the market. With no need to build charging stations, as well as other advantages, wireless charging is gaining market favor in the field of partial charge. From the perspective of operation modes, most charging facility operators will move from operations with

a sole dependence on charging fees to diversified operations that combine other value-added services such as advertising, insurance, finance, car selling and leasing, and big data of automobile industry on the basis of charging piles.

7. Conclusion

China's new energy vehicles are still in the industrial start-up phase, and their development is mainly policy driven. During the 13th Five-Year Plan period, the industry will gradually enter into the rapid development period under the drive of market from the nurturing stage under the drive of policy during its maturity development. According to the planning objectives in the *Energy-Saving and New Energy Vehicles Industry Development Plan (2012–2020)*, the goal for the cumulative production and sale of pure EVs and plug-in hybrid vehicles is more than 5 million by 2020. However, industrial development still has a long way to go. In the future, it will be necessary to accelerate the improvement of policy support and standard systems; strengthen independent innovation and the integration of global technology resources; improve product technical levels, and especially safety levels; and simultaneously improve infrastructure construction and aftermarket mechanism to gradually solve application problems and thus ensure the synchronous development of "quantity" and "quality" in the industry.

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