

SYSTEM INNOVATION: CASE STUDIES

CHINA - The Case of Electric Vehicles



Case Study on System Innovation in China

The Case of Electric Vehicles

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Introduction

This country case study was compiled within the OECD TIP project on System Innovation. The conceptual framework for this project is formulated in *System Innovation: Concepts, Dynamics and Governance* (DSTI/STP/TIP (2013)3). Aims of the TIP project are the clarification of the concept of system innovation and the identification of common good governance approaches. The main objectives of the country case study is the identification of key self-reinforcing mechanisms that can act as drivers / bottlenecks and of a suited ,policy-mix, as well as potential policy gaps/bottlenecks.

A system under study should be a socio-techno-economic system which includes a set of stakeholders, institutions, infrastructure, and connections – spanning researchers to end-users – that share a common societal function. The system innovation is defined as a radical innovation in socio-technical systems that fulfil societal functions, entailing changes in both components and architecture of related elements (DSTI/STP/TIP (2013)3). It is characterized by: fundamentally different knowledge base and technical capabilities that either disrupt existing competencies and technologies or complement them leading to “new combinations”, changes in consumer practices and markets, and changes in infrastructure and other elements (e.g. policy, cultural meaning).

In China, the electric-vehicle industry is such a system which emerged as of 2001. The electric vehicles include battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell vehicles (FCVs). The transition of electric vehicle industry covers a series of changes from strategies and policies in central and local governments to behaviors of industries and consumers. It's experiencing a different pathway of development from traditional internal-combustion-engine vehicle industry in China. It would change the landscape of Chinese automobile industry if it achieves the goals set by Chinese government. Therefore the electric vehicle industry satisfies the criteria of case study under the OECD System Innovation Project.

The case study includes five chapters. The first chapter explains the rationale for case study selection. Following it is characterization of system transition stage. The third chapter describes the transition mechanism and bottlenecks of electric vehicle industry. Then policies and measures for electric vehicles are explored. Finally lessons learned of EV development in China in the past 15 years will be drawn.

1. Rationale for case study selection

According to the China Association of Automobile Manufacturers, China surpassed the United States to become the world's largest automobile market in 2009 with a record 13.9 million vehicles sold in the country, compared to 10.43 million cars and light trucks sold in the United States. There is a quickly growing demand for transport in China as more and more people can afford to buy cars. Chinese government believes electric vehicles would offer China enormous potential to achieve industry leadership and address the shortage of oil-based fuel and environmental pollution. In June 2012, the State Council

issued the *Plan of Energy-Saving and New Energy Vehicle Industry Development (2012-2020)* (Guofa [2012] No.22) which adapted a phased introduction of electric vehicles and set a goal for electric vehicle industry development in various phase. The Plan is targeting the production of 500,000 BEVs and PHEVs by 2015, with the production capacity to grow to 2 million units and the cumulative production and sales of more than 5 million of those types by 2020.¹

Criteria for case study selection

- a) *The electric vehicle is seen as a means to address highly desirable benefits such as reduction of carbon dioxide emissions and air pollution.*

In recent years, China's pollution problem caused by motor vehicle is increasingly seriously. In 2012, China had 224 million motor vehicles whose emissions become the main source of air pollution in China, which is the important cause of the haze and photochemical smog pollution (MOEP, 2014). According to a analysis by Beijing Municipal Environmental Protection Bureau, 31% of PM_{2.5} in Beijing is as a result of motor vehicle.² EVs also have the potential to reduce carbon dioxide emissions by 13-68% compared to internal combustion engines (ICEs) (The Climate Group, Bain & Company, 2010). With the help of the advanced V2G (vehicle-to-grid) technology, deployment of EVs can directly decrease the emission of carbon dioxide and other pollutants within a vehicle's lifecycle, which will significantly relieve air pollution in cities. Through peak-shaving (sending power back to the grid when demand is high), EVs can also indirectly reduce carbon dioxide emissions.

- b) *The electric vehicle plays an important role in dealing with shortage of oil-based fuel in China.*

China's economic development results an increasing demand for oil. China became a net oil importer in 1993 and imported 57.6% of its oil in 2013, with 208 million tons crude oil produced domestically and 282 million tons imported. The figure is expected to grow in future. At the same time, China became the largest automobile market in the world by the end of 2009 and owned 137 million cars in 2013. Automobile industry is the primary factor driving oil consumption, which is estimated to account for more than a third of oil consumption. Developing EVs will assist China's energy conservation. The energy efficiency of EVs is 46% higher than ICEs. China is rich in coal reserve. At the same time, nuclear energy, wind energy, solar energy will become main sources of electric power in future. Therefore, to develop EVs can reduce China's dependence on imported oil.

- c) *Developing electric vehicle gives China an opportunity to leapfrog its global competitors in this emerging industry.*

Since 2009, China has become the world's largest car production and marketing country for four consecutive years. One of its biggest shortcomings is its outdated gasoline engine technology. Chinese government recognized that domestic automakers probably couldn't catch up with their global rivals' internal-combustion-engine technology anytime soon.

¹ The State Council, Plan of Energy-Saving and New Energy Vehicle Industry Development 2012-2020 (Guofa [2012] No.22), 28 June, 2012.

² Director of Beijing Municipal Bureau of Environmental Protection: about 70% of PM_{2.5} come from Beijing, The Beijing News, 16 April, 2014, http://news.ifeng.com/mainland/detail_2014_04/16/35794376_0.shtml

However in the electric vehicle field, domestic enterprises have accumulated certain experience. A large domestic market for electric vehicles would give Chinese automakers an excellent launchpad to reach the world stage. They had the potential to assume a leading position in the fledgling electric-vehicle segment. The government hoped this approach could succeed if Chinese companies rapidly brought battery-electric vehicles to mass production and consolidated technological advances in batteries, traction motors, and power electronics.

d) The transition of electric vehicle transport system covers a series of changes and need long-run effort.

The transition of electric vehicle transport system covers a series of changes from strategies and policies in central and local governments to behaviors of industries and consumers. Especially consumers' demand for long-distance travel has not been satisfied by EVs on market. Developing electric vehicles and transiting to an ideal system is a long-run course. According to a McKinsey report, China scored 1.5 (full score is 5) in McKinsey's electric-vehicle index which assesses a nation's electric-vehicle readiness in terms of supply and demand. Furthermore, in overall electric-vehicle readiness, China fell from third place, in July 2010, to fifth, in January 2012—behind Japan, the United States, France, and Germany (Axel Krieger, et al, 2012). This long-run course needs sustainable policy involvement and other intervention.

e) Success could only be achieved through concerted public and private investments.

Development of EV industry in China requires enterprises play a leading role in national innovation system. Enterprises should also be the core of the advances in science and technology. However, currently China's capacity for EV development remains inadequate. Also at the very early of transition, enterprises will be faced large failure risk. Hence governmental investment is necessary and important for EV development at this stage and will gradually quit as the transition is maturing,

f) Development of electric vehicle covers different layers of systems - Technological, Social, Industrial, Economic, and Policy.

Development of EVs covers multiple dimensions – social, technological, industrial, economic, and policy, which is in line with the characteristics of system innovation. The case study will address the technological progress and bottlenecks of EVs in China, the consumer's habit of traveling by cars, the development of auto enterprise and related enterprises in China, and governmental policies for supporting the EV development.

g) Multilayer governance challenges are facing the system transition especially at its early stage.

China's EV development involves different stakeholders, that is, central and local governments, EV enterprises, consumers and so on. At the early stage, how an appropriate governance structure should be built, how the governance should play a role in defining the goal and roadmap of transition, are challenges facing the China's EV development. This issue will be also addressed in the case study.

2. Characterization of System Transition Stages

2.1 Historical development of electric vehicle in China

China's cause of developing electric vehicles started from 2001 when the Ministry of Science and Technology (MOST) launched the *Electric Vehicle Special Project under the Tenth Five-Year (2001-2005) National High-Tech R&D Program (863 Program)* which covered HEVs, BEVs and FCVs (the so-called "three verticals") and multi-source energy power control unit (PCU), drive motor system, and battery and battery management system (BMS) (so-called "three horizontals"). The Project marked that China's electric vehicle industry started a phase of full-fledge development.

In April 2006, the MOST launched the *Energy-Saving and New Energy Vehicle Major Project under the Eleventh Five-Year 863 Program*, which continued the "three verticals and three horizontals" framework with the focus on the EV's power system technology platform and key components.

During the Beijing Olympic Games in 2008, 595 BEVs, HEVs and FCVs were used to serve the Games. It has achieved the largest scale of pilot operation of EVs in the history of Olympic Games with an accumulated running distance of 3.71 million kilometers and total passenger transportation of 4.42 million person-times.³

On 20 March, 2009, the State Council issued the *Auto Industry Restructuring and Revitalization Plan* which put forward the new energy auto industry strategy for the first time and would invest RMB10 billion for the industrialization of new energy vehicle.

In January 2009, 13 cities (Beijing, Shanghai, Chongqing, Changchun, Dalian, Hangzhou, Jinan, Wuhan, Shenzhen, Hefei, Changsha, Kunming, and Nanchang) were chosen as pilot cities for promoting usage of new energy vehicles in public sector.⁴ In 2010, 12 cities (Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan, Guangzhou, Shenyang, Chengdu, Huhhot, Nantong, and Xiangyang) were added into the list of pilot cities. Moreover, personal purchasing new energy vehicle will be subsidized in six cities, namely, Beijing, Changchun, Hangzhou, Hefei, Shanghai, and Shenzhen.

On 10 October, 2010, new energy vehicle were listed as one of seven strategic emerging industries by the State Council.⁵ In March 2012, the MOST published the *Twelfth Ten-Year Special Plan for Science and Technology Development of Electric Vehicle* which aimed at making China as one of advanced countries in energy-saving and new energy vehicle industry through research, development and innovation.⁶ In June 2012, the State Council issued the *Plan of Energy-Saving and New Energy Vehicle Industry Development (2012-2020) (Guofa [2012] No.22)* which confirms that the BEV is the main direction of new energy vehicle industry development. It adapted a phased introduction of electric

³ The Ministry of Science and Technology, Summary of Energy-Saving and New Energy Demonstration During 2008 Beijing Olympic Games, 10 November, 2008. http://www.most.gov.cn/kjbgz/200811/t20081107_64905.htm.

⁴ The Ministry of Finance, the Ministry of Science and Technology, Provisional Measures on Management of Fiscal Subsidy for Energy Saving and New Energy Vehicle Demonstration and Promotion (Caijian [2009] No. 6), 23 January, 2009.

⁵ The State Council, Decision on Accelerating the Fostering and Development of Strategic Emerging Industries (Guofa [2010] No. 32), 10 October, 2010.

⁶ the Ministry of Science and Technology, Special Plan of Science and Technology Development of Electric Vehicles in the 12th Five-Year (Guokefaji [2012] No. 195), 27 March, 2014.

vehicles and set a goal for electric vehicle industry development in various phase. The Plan is targeting the production of 500,000 BEVs and PHEVs by 2015, with the production capacity to grow to 2 million units and the cumulative production and sales of more than 5 million of those types by 2020.

In September 2013, a new round of promotion and application of new energy vehicles were launched.⁷ So far, total 39 city (clusters) or regions were identified to promote the application of new energy vehicles.

In 2014, China produced 78499 EVs and sold 74763, up 9.4 times and 9.2 times over the period of 2011 respectively, in which the production and sales of BEVs had grown by 8.6 times and 8.1 times, and production and sales of PHEVs by 4.8 times and 5.2 times respectively⁸.

2.2 Current stage of EV industry development

Development of EV's Technology

With Chinese government's support to research and development for many years, currently China has preliminarily mastered the core technologies of EV power system platform and key components. It has basically established a technology innovation system of "three vertical (HEV, BEV and FCV) and three horizontal (multi-source energy power control unit (PCU), drive motor system, and battery and battery management system (BMS)) and "three platforms" (the standard test platform, energy supply platform, and integrated demonstration platform). It has also formed a relatively comprehensive capability of basic research, product development, and test and evaluation. China has achieved a major breakthrough in some key technologies, mainly reflected in the following aspects.

First, the PHEV technology made great progress. At present, the plug-in hybrid technology is mainly used in passenger cars. Some PHEV models close to international advanced level.

Second, BEV technology is increasingly matured and ready to commercialize. Some domestic automakers have mastered the core technologies in vehicle powertrain matching and integration, and vehicle control. They have capability to develop BEVs close to international advanced level.

Third, significant progress was made in FCV technology. So far, China has preliminarily grasped core technologies in finished vehicle, power system and key components; built up BEV powertrain technology platform with own intellectual property rights; formed a complementary research system of key components, including the fuel cell engine, power batteries, DC/DC converter, drive motor, hydrogen storage and supply and so on.

Fourth, obviously progress has been made in key components. In terms of power battery, domestic automakers have preliminarily had product research and development capabilities and production equipment design and manufacturing capabilities. Power

⁷ The Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, National Development and Reform Commission, Notice on Continuing to Promote and Apply Electric Vehicles (Caijian [2013] No. 551), 29 September, 2013.

⁸ China Association of Automobile Manufacturers, Statistics on Chinese auto industry, December 2014, <http://www.caam.org.cn/xiehuidongtai/20150112/1805144355.html>

battery performance indicators gradually reach to international advanced level. The lithium ion battery anode materials and electrolyte has realized domestic production. In terms of drive motor system, the main technical indicators reach the international level. In electric control system, China has initially formed small batch production ability of hybrid system and pure electric drive system.

However, compared with the leading competitors abroad, China still lags behind in the following aspects.

Domestic PHEV producers did not fully grasp the specific technology of plug-in hybrid engine and mechanical and electrical coupling drive system which caused the plug-in hybrid system integrated design level is relatively backward. Moreover the engineering level of finished vehicle and parts needs improvement. Products are at the early stage of industrialization, and their cost is high. Also the oil-saving rate and reliability of the finished vehicle needs to be improved.

In the BEV filed, China is still short of some core technology. BEV with high performance lags behind that of the foreign advanced products in terms of reliability and engineering capabilities. Part of components and materials needed by the motor and battery should be imported. At the same time, some key spare parts such as chip, IGBT (Insulated Gate Bipolar Transistor), controller hardware, signal processing and amplification components still rely on imports.

Demonstration and promotion of EVs

Demonstration of EVs in 2008 Beijing Olympic Games and Paralympic Games, 2010 Shanghai World Expo and the 26th Shenzhen Summer Universiade in 2011

2008 Beijing Olympic Games has been the first Olympic Games took place in China. Three concepts were put forward to build Olympics into “green Olympics, Hi-Tech Olympics and Humanistic Olympics”. In order to realize the concept of “green Olympics”, the largest scale of pilot operation of EVs in the history of Olympic Games was launched. During the Beijing Olympic Games and Paralympics Games in 2008, 595 BEVs, HEVs and FCVs were used to serve the Games, with an accumulated running distance of 3.71 million kilometers and total passenger transportation of 4.42 million person-times.⁹

During the 2010 Shanghai World Expo, 1147 EVs were put in to operate including 500 HEVs, 451 BEVs and 196 FCVs. The transportation in Expo Park had realized zero emissions. In the period of the demonstration operation for 184 days, the total mileage of EVs reached near 30 million km, among them, mileage of HEV were more than 20 million km, BEV near to 0.7 million km and FCV 0.9 million km (Peng Aizhen, 2012).

The 26th Shenzhen Summer Universiade was held on August 12-23, for which 1999 EVs were invested to serve. According to incomplete statistics, during the Universiade, all kinds of EVs had accumulated mileage of more than 4 million km, with transport volume of 6.04 million person-times and no security accident. Compared with the traditional fuel

⁹ Ministry of Science and Technology, Summary of Energy-Saving and New Energy Demonstration During 2008 Beijing Olympic Games, 10 November, 2008. http://www.most.gov.cn/kjbgz/200811/t20081107_64905.htm.

vehicle, the EV demonstration operation during Universiade had reduced emissions of 1028 tons of carbon dioxide in shenzhen city.¹⁰

First round of demonstration and promotion of EVs in 25 pilot cities

In January 2009, 13 cities (Beijing, Shanghai, Chongqing, Changchun, Dalian, Hangzhou, Jinan, Wuhan, Shenzhen, Hefei, Changsha, Kunming, and Nanchang) were chosen as pilot cities for promoting usage of new energy vehicles in public sector.¹¹ In 2010, 12 cities (Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan, Guangzhou, Shenyang, Chengdu, Huhhot, Nantong, and Xiangyang) were added into the list of pilot cities.¹² Moreover, personal purchasing new energy vehicle will be subsidized in six cities, namely, Beijing, Changchun, Hangzhou, Hefei, Shanghai, and Shenzhen.¹³

According to their EV demonstration and promotion plans, the 25 cities would promote 51707 EVs in public sector, with 19341 BEVs and 30982 HEVs (including PHEVs and start-stop energy-saving vehicles). Six cities would promote 132100 EVs in private sector, with 70100 BEVs and 62000 PHEVs by the end of 2012.

In late December 2012, the Ministry of finance (MOF), the Ministry of Industry and Information Technology (MIIT), the MOST, and the National Development and Reform Commission (NDRC) evaluated the performance of the EV demonstration and promote pilot work in 25 pilot cities. Main findings can be summed up in the following three aspects¹⁴.

In terms of the number of EVs promoted, by the end of 2012, 25 cities altogether promoted more than 27400 EVs, including more than 23000 EVs in public service sector and more than 4400 EVs purchased by personal consumers. According to statistics by EV type, more than 12100 were hybrid electric bus, 3700 were hybrid passenger car, 2500 were pure electric bus (including the plug-in electric bus), 6800 were pure electric passenger cars (including the plug-in electric passenger cars), 2100 were other type of EVs. The number of EV prompted in 2012 had increaed by 1.4 times compared to that in 2011.

Hybrid bus has the best promotion effects. The fuel consumption for 100 km is under 24 liters. By the end of May 2013, hybrid bus sold nationwide were over 5000 units. Pure electric passenger cars (including the plug-in) has largely growth in 2012. Power battery technology was improved in terms of reliability and safety. BEVs for short logistics and postal service were promoted quickly.

25 pilot cities built a total of more than 170 charging power stations, more than 8100 charging piles. Scattered charging pile, concentrated charging station and battery

¹⁰ The Ministry of Science and Technology, New Energy Vehicle Demonstration Succeed in Shenzhen Universiade Success, 14 October, 2011, http://www.most.gov.cn/kjbgz/201110/t20111013_90282.htm.

¹¹ The Ministry of Finance, the Ministry of Science and Technology, Notice on Demonstration and Promotion Pilot of Electric Vehicles (Caijian [2009] No. 6), 23 January, 2009.

¹² The Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, National Development and Reform Commission, Notice on Scaling-up Demonstration and Promotion of Electric Vehicle in Public Sector (Caijian[2010] No. 227), 31 May, 2010.

¹³ The Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, National Development and Reform Commission, Notice on Subsidy Pilot to Personal Purchasing Electric Vehicles (Caijian[2010] No. 230), 31 May, 2010.

¹⁴ Zhou Qingwen, Lu Liqin, Su Bo: Electric Vehicle Development Achived Great Progress, China Industry Newspaper, 19 July, 2013, <http://www.cinn.cn/xw/ztzl/bzftghznhg/296837.shtml>

exchange station were all put into service. Infrastructure construction achieved better results in Shenzhen, Hangzhou, Beijing, Chengdu, Hefei, Dalian. A national standard on, charging interface has been widely used.

Overall, the first round of EV demonstration and promotion has achieved some effects, but also exposed some problems existing in its industrialization and consumption. one is the actual number number of EV promoted were far from its target of 184,000. Other other is that the EV promotion in private sector has a long way to go to realize its objectvie. Meanwhile, privately purchased EVs were mainly in Shenzhen and Hefei two main cities, the number of EVs purchased by personl consumers in other four pilot cities was extremely limited.

New round of promotion and utilization of EVs

On September 13, 2013, the Ministry of Finance (MOF), the MOST, the Ministry of Industry and Information Technology, and the National Development and Reform Commission (NDRC) jointly issued the *Notice on Continuing to Carry out The Promotion and Utilization of New Energy Vehicles (caijian [2013] No. 551)* which covered the period from 2013 to 2015. Two batches of cities or city clusters were selected to promote and utilize EVs in November 2013 and January 2014 separately, amounting to 39 cities or city clusters: Beijing, Changchun, Chengdu, Chongqing, Dalian, Guangzhou, Harbin, Haikou, Hefei, Jincheng, Lanzhou, Liucheng, Linyi, Luzhou, Ningbo, Qingdao, Shanghai, Shenyang, Shenzhen, Taiyuan, Tianjin, Weifang, Wuhu, Wuhan, Xi'an, Xiangyang, Xinxiang, Zhenzhou, Zibo, Chang-Zhu-Tan region, city cluster in Fujian province, city cluster in Guangdong province, city cluster in Guizhou province, city cluster in Hebei province, city cluster in Jiangsu province, city cluster in Jiangxi province, city cluster in Inner Mongolia, city cluster in Yunnan province, and city cluster in Zhejiang province.

According to the application plans of these 39 cities and city clusters, they will promote and utilize 336 thousand Evs during the period from 2013 to 2015. In November 2014, the MIIT published the achievement of EV promotion and application in the 39 cities or city clusters. From January 2013 to the end of September 2014, they promoted and utilized 38600 EVs, with 20500 EVs during January to September 2014. The averagy rate of target achievment is 11%, with the highest rate of 72% in Hefei and zero in six cities (see Table 1)¹⁵.

Table 1 Achievement of EV promotion and utilization target in 39 cities and city clusters

No.	City (cluster)	Target for 2013 -2015 (unit)	Amount of EVs promoted and utilized by the end of September 2014 (unit)	Completi on rate
1	City cluster in Zhejiang province	10100	5203	52%
2	Beijing	35020	4762	14%
3	Shenzhen	35000	4189	12%
4	Hefei	5720	4145	72%
5	Shanghai	10000	4022	40%

¹⁵ The Ministry of Industry and Information Technology, Promotion of New Energy Vehicles, 21 Novenber, 2014, <http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/16271311.html>

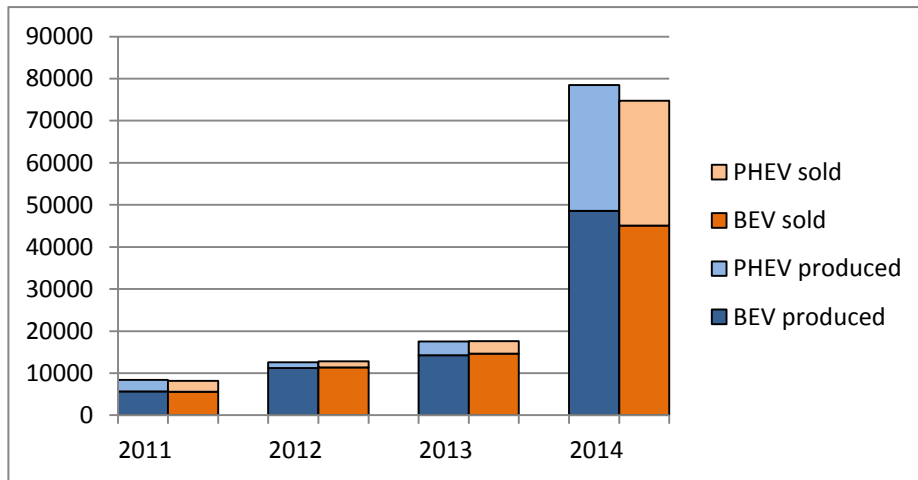
6	City cluster in Jiangsu province	18085	3118	17%
7	Tianjin	12000	1726	14%
8	Zhengzhou	5500	1423	26%
9	City cluster in Guangdong province	10000	1369	14%
10	Guangzhou	10000	1241	12%
11	Chongqing	10000	995	10%
12	City cluster in Hebei province	13141	803	6%
13	Xi'an	11000	710	6%
14	Xiangyang	5000	561	11%
15	Qingdao	5200	510	10%
16	Chang-Zhu-Tan region	6100	492	8%
17	Taiyuan	5000	489	10%
18	Wuhan	10500	389	4%
19	Chengdu	5000	298	6%
20	Wuhu	5110	252	5%
21	Shenyang	5000	232	5%
22	Dalian	5000	225	5%
23	City cluster in Yunnan province	5000	223	4%
24	Weifang	5500	174	3%
25	Linyi	5690	173	3%
26	City cluster in Guizhou province	6000	166	3%
27	Xinxiang	5000	153	3%
28	City cluster in Fujian province	10000	153	2%
29	Ningbo	5000	119	2%
30	City cluster in Jiangxi province	5300	118	2%
31	Zibo	5000	63	1%
32	Luzhou	5000	48	1%
33	Changchun	10000	33	0%
34	City cluster in Inner Mongolia	5000	25	1%
35	Harbin	5000	5	0%
36	Jincheng	6000	3	0%
37	Lanzhou	5000	3	0%
38	Liaocheng	5010	3	0%
39	Haikou	5000	0	0%

Source: the MIIT, 2014.

EV Production and Sales

Although it is still far away from the goal of production of 500,000 BEVs and PHEVs by 2015, production and sales volume of EVs in China grew rapidly in the past four years. In 2014, China produced 78499 EVs and sold 74763, up 9.4 times and 9.2 times over the period of 2011 respectively, in which the production and sales of BEVs had grown by 8.6 times and 8.1 times, and production and sales of PHEVs by 4.8 times and 5.2 times respectively.

Figure 1 Production and sales volume of EVs, 2011-2014



Source: Statistic based on data provided by China Association of Automobile Manufacturers.

The competitiveness of Chinese EV enterprises has improved to a large extent with regard to their share of EV sales and rank in the EV makers worldwide. But the overall competitiveness of the whole industry is still lagging behind international competitors. Compared to 2013, there are two Chinese EV enterprises, BYD and Kandi, listed in the top 10 EV makers in 2014. However, four Chinese EV enterprises (BYD, Kandi, Zotye and BAW) which entered the list of top 20 EV enterprises worldwide only accounted for 14% of the EV market worldwide (see table 2 below).

Table 2 Top 20 EV enterprises worldwide in 2014

Rank in 2014	EV maker	Sales in 2014	Market share (%)	Rank in 2013
1	Nissan	63327	20	1
2	Mitsubishi	36670	12	3
3	Tesla	31623	10	5
4	Gm Chevrolet	22509	7	2
5	Ford	22436	7	7
6	Toyota	20470	6	4
7	BYD	18358	6	11
8	Renault	18358	6	6
9	BMW	17793	6	14
10	Kandi	11307	4	N/A
11	Volkswagen	9703	3	13
12	Geely	8605	3	9
13	Zotye	7542	2	23
14	Smart	5824	2	10
15	BAW	5234	2	16
16	Volvo	5182	2	8
17	Porsche	1954	1	22
18	Fiat	1799	1	18
19	Cadillac	1354	0	29

20	KIA	1340	0	N/A
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Source: Southmoney, Global list of electric vehicle enterprises by EV sales, 10 February, 2015.
<http://www.southmoney.com/shuju/hysj/201502/279437.html>

Charging infrastructure construction

The number of charging stations in China had rapid increased from 76 in 2010 to 518 in 2013, and the number of charging pile had grown from 1122 to 22528 during the same period. By the end of 2013, the State Grid had built 19,000 EV charging piles and 400 charging/battery swap stations (including 209 charging stations and 191 battery swap stations), in contrast to 3,528 charging piles and 118 charging/battery swap stations established by China Southern Power Grid, which lays stress on the construction of intelligent charging/battery swap service network in the Pearl River Delta region (Shenfuyuan, 2014).

2.3 Characterizing the stage of transition

EV is an emerging industries, which has obvious gap with traditional internal-combustion-engine vehicle regarding the technical maturity of product, purchase cost, driving range and convenience. They are the common problem facing all countries who ae dedicated to develop EV industry.

From the perspectives of technology, industry and market, **the EV system in China is till at its early stage of transition.** Although achieved great progress in EV technology, China still lags behind its advanced competitors, lacks some core technologies and core components. The overall quality of EV is far from the expectation of consumers. EV demonstration program in 25 cities for three years from 2009 to 2012 promoted 27,400 EVs but most in public sector and hasn't reached its objective of 184,000. EV production and sale grows rapidly but is far away from the goal of 500,000 by 2015. In 2013, the sale volume of EV only counted for 0.08% of traditional internal-combustion-engine vehicles.

Also China's EV market maturity is quite low. According to a McKinsey report, China scored 1.5 (full score is 5) in McKinsey's electric-vehicle index which assesses a nation's electric-vehicle readiness in terms of supply and demand. Furthermore, in overall electric-vehicle readiness, China fell from third place, in July 2010, to fifth, in January 2012—behind Japan, the United States, France, and Germany (Axel Krieger, et al, 2012).

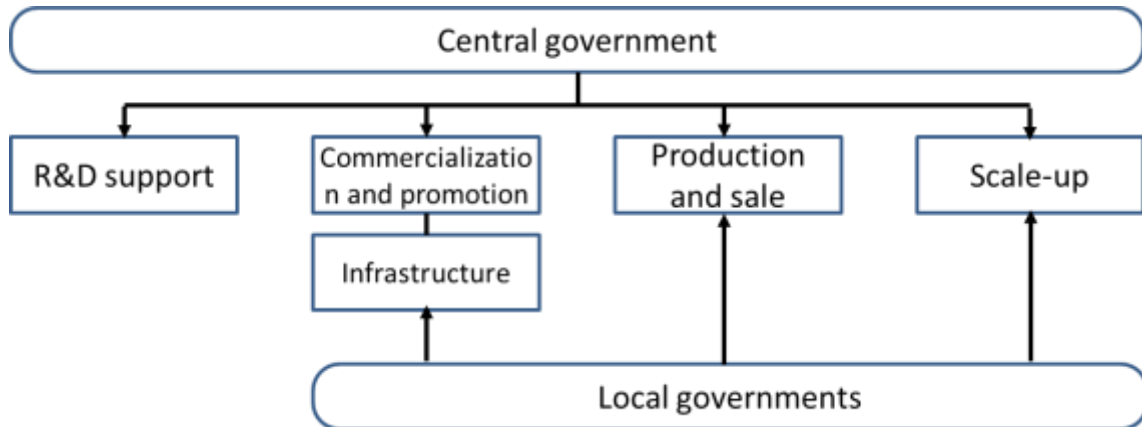
3. Transition Mechanism and Bottlenecks

3.1 Transition mechanism and driver

China's EV development is driven by a top-down approach. The central government is the initiator and main driver for the EV development. The central government supports every stage of the system from R&D, demonstration and promotion, commercialization to production and sales, scale-up, and charging infrastructure construction. In order to response to policies of central government, local governments also provide support to EV production and sales, and charging infrastructure construction. The role of market in

transition is relatively weak. So far the subsidy policy of government is the main driver of EV enterprises to produce EVs and consumers to buy EVs.

Figure 2 Transition mechanism of EV system



3.2 Transition bottlenecks

Charging Infrastructure is still far from the demand of charging EVs.

As EVs need to be charged by charging stations, a certain amount of charging stations are essential for promoting new energy vehicles. And charging facilities like charging stations are hardware for the development of EVs, perfect supporting charging facilities will be the key to massive roll-out of EVs. Therefore, EVs and charging facilities are supplementary to each other. Currently, the biggest problem faced by popularization of EVs in China is still the over slow construction of charging station. By the end of 2013, there are 518 charging stations and 22528 charging pile in China, which is far from the objectives of 2000 charging/battery swap station and 400,000 charging piles in 2015.¹⁶

The reasons of slow construction of charging infrastructure consist in two aspects. On one hand, due to rapid development cities lack land in urban area to build charging stations. On the other hand, in order to reduce consumers' cost of using EVs, government has limited the price of electricity paid by consumers when they were charging their EVs in charging station.¹⁷ Although charging station runners can charge service fee, charging stations are in deficit. 400 charging/battery swap stations built and operated by the State Grid are all in deficit. Seven stations in Shenzhen built by China Southern Power Grid got a loss of 13 million yuan per year. Thus enterprises are not actively to build charging stations.

Under the huge pressure of this task, State Grid had to open the construction of charging station to private capitals. In May 27, 2014, State Grid conducted press conference to announce that the project of connecting distributed generation to the national power grid and the field of electric vehicle charging facilities were opened to private capitals.

¹⁶ The Ministry of Science and Technology, Special Plan of Science and Technology Development of Electric Vehicles in the 12th Five-Year (Guokefaji [2012] No. 195), 27 March, 2014.

¹⁷ National Development and Reform Commission, Notice on Related Issues of Electricity Price Policy for Electric Vehicles (Fagaijiage [2014] No. 1668), 22 July, 2014.

Short of some core technology limited the improvement of EV's quality

Chinese EV enterprises are still short of some core technology. BEV with high performance lags behind that of the foreign advanced products in terms of reliability and engineering capabilities. Part of components and materials needed by the motor and battery should be imported. At the same time, some key spare parts such as chip, IGBT (Insulated Gate Bipolar Transistor), controller hardware, signal processing and amplification components still rely on imports. These limited Chinese EV enterprises to develop new model of EVs and improve their quality.

Consumers are not interested in purchasing EVs once there is no subsidy.

According to GfK's Electric Vehicle Study 2013 which surveyed nationally representative samples of customers across 6 different markets to study global opinion and attitudes towards EVs, Chinese consumers was least interested in EVs due to price and reliability concerns (GfK, 2013). Opinion and feelings toward electric vehicles in China (with 3105 respondents) are not as yet formed. The majority has a neutral impression (60%), there are few with a favorable opinion (16%) and only one in five (20%) are open to considering them for purchase. The main barrier in China is its insufficient driving range. Over three quarters see the non-personal benefits of 'low emission' as being most applicable to electric vehicles, while the direct personal benefits are not widely perceived. Only a half see EVs as 'easy to operate' and less than half as 'low maintenance cost' or 'safe'. In particular, only a third associated them with 'great value for money' or 'reliable'. Other countries surveyed are Japan, France, Spain, Russia and the USA.

Table 3 Results of GfK's survey of electric vehicles in six major markets

Country	Awareness Know a fair amount / know very well	Current opinion Very or mainly favourable	Consideration Somewhat or very open	Consideration Not very or not at all open	Segment most likely to consider
Japan	61%	82%	63%	26%	luxury (imported) brand station waggon - 76%
Russia	30%	72%	49%	17%	luxury brand mini / small car - 81%
Spain	15%	65%	46%	33%	luxury brand standard car - 55%
France	27%	61%	35%	34%	luxury brand crossover car - 47%
USA	32%	36%	45%	32%	[n/a]
China	12%	16%	20%	46%	non-luxury brand mini / small car - 28%

Source: GfK, 2013.

Local protection makes a fragmented EV market

Individuals who buy an EV will enjoy the subsidies from central government and subsidies from local government as well if the EV model entered the local EV directory. Some local governments thought subsidies to EV model produced by non-local

enterprises is not cost-effective. Therefore, some local EV directory excluded EV model of non-local enterprises. The policy requires that local EV directory give at least 30% share of non-local EV brands. However, this also is equal to admit the appropriateness of 70% share of local EV brands. EV enterprises should look at the national and global market, local protection limits the development of enterprises and make the EV market fragmented, which negatively impact the development of national EV market.

4. Strategy, Policies and Measures for Electric Vehicles

The government has established a policy framework to accelerate electric-vehicle technology development, while encouraging market transformation that will support research and development, regulate the industry and encourage consumption. The policy framework cover policies and measures in supply side as well as those in demand side.

4.1 Strategy for electric vehicle industry development

In June 2012, the State Council issued the *Plan of Energy-Saving and New Energy Vehicle Industry Development (2012-2020)* (Guofa [2012] No.22) which is the national strategy for EV industry development. It adapted a phased introduction of electric vehicles and set a goal for electric vehicle industry development in various phase.

Technological roadmap

Drive with pure electric power shall be the main strategic orientation of the development of new energy automobiles and systemic transformation of the automobile industry. At present, priority shall be given to boosting the industrialization of battery electric vehicles and plug-in hybrid electric vehicles

Objectives

The Plan set objectives in the following aspects.

Great progress made in industrialization. The Plan is targeting the production of 500,000 BEVs and PHEVs by 2015, with the production capacity to grow to 2 million units and the cumulative production and sales of more than 5 million of those types by 2020.

Substantial improvement of technological capability. The technologies of EVs, power batteries and crucial parts and components shall have, generally, reached the advanced international standards. A number of relatively highly competitive EV enterprises shall have formed.

Obvious strengthening of the support capacity. The technological level and the scale of production of crucial parts and components shall have basically met the demand of the domestic market. The construction of electric charging facilities shall have been in compatibility with the production and sales volume of EVs and in satisfaction of demand for the operation of EVs in key regions or between cities.

Relatively sound management systems. Effective management systems on EV enterprises and their products shall have been established, marketing and after-sales service system

and power batteries recycling systems shall have been established, and support policies shall have been improved to form relatively sound systems of technical norms and standards.

Development steps

The EV development in China is divided into two phases - industry incubation period by 2015 and industry development period from 2016 to 2020. By 2015, government will take efforts to carry out pilot demonstration and to speed up cultivating the market, so as to promote technological progress and industrial development. During the industry development period, market should fully play a role in guiding the industry development, thus to promote large-scale commercial applications of EVs.

Strategic measures

The Plan put forward five main strategic measures to promote the industrialization of EVs: (1) to implement the New Energy Automobile Technology Innovation Project, (2) to scientifically formulate industry development structure, (3) to speed up the application and pilot demonstration, (4) to actively promote charging infrastructure construction, and (5) to strengthen power battery cascade utilization and recycle management.

4.2 Supply-side policies and measures

R&D projects supported under national S&T programs

During the period of tenth five-year plan (2001-2005), the MOST launched an Electric Vehicle Major Project under the National High-Tech Research and Development Program (the 863 Program). The project firstly put forward a technology research framework of “three verticals” (HEV, BEV and FCV) and “three horizontals” (multi-source energy power control unit (PCU), drive motor system, and battery and battery management system (BMS)). Supported by the Project, prototype EVs had been developed. Four hybrid vehicle and BEV models were entered the auto announcement directory. Great technological progress had been made in power battery, drive motor, electronic control unit and other key components. 796 patent applications were submitted at home and abroad. Seven public inspection and test platforms were established. 26 national standards were issued. Eight cities, including Beijing and Wuhan, carried out demonstration operation of EVs¹⁸.

During the period of 11th five-year plan (2006-2010) the 863 Program initiated the Energy-Saving and New Energy Vehicle Major Project. In accordance with the “three verticals and three horizontals” framework, 270 projects were selected in key components energy-saving and new energy vehicle, power system, vehicle integration, testing platform, demonstration and promotion, and standard and policy. The project totally invested 7.5 billion yuan, of which 1.16 billion yuan was from fiscal funds. 14600 researchers from 432 EV enterprises, research institutes and universities participated in the Project. With the support of the Projects, 350 EV models were entered national auto announcement directory, 59 EV standards at national level or industrial level were formulated, 15 national key laboratories and engineering technology research centers and

¹⁸ The Ministry of Science and Technology, Electric Vehicle Major Project in the Tenth Five-Year Succeed, 10 February, 2006, http://www.most.gov.cn/kjbgz/200602/t20060209_28619.htm

48 EV research and development platforms were built. 2011 patent applications were submitted, including 1015 invention patent applications¹⁹.

During the period of 12th five-year plan (2011-2015), the 863 Program launched the Electric Vehicle Key Technology and System Integration Major Project. The Project is aiming at strengthening EV technological breakthrough, advancing the EV R&D for industrialization, building a technological innovation system led by enterprises and collaborated by research institutes and universities, so as to support and lead the technology progress and great-leapfrog-forward development of China's automobile industry. Priorities of the Project are given to break through the performance bottlenecks of hybrid vehicles, to develop series of BEV and its energy supply systems, to develop high-end cutting-edge technology such as FCVs and build the next generation pure electric power system technology platform, and to develop the next generation BEVs. 77 subjects were funded by 738 million yuan²⁰.

Government support for commercialization of electric vehicles and their key components

In order to speed up the technical innovation and industrialization of new energy automotive industry, in 2012 the MOF, the MIIT and the MOST implemented the New Energy Automobile Industry Technological Innovation Program. It focuses on BEV, PHEV and FCV and power battery. 25 key projects were supported under the Program. The EV enterprises who implemented these projects will receive 40% of total award after project launched, 50% after mid-term evaluation, and 10% after project finished.

Tax credit for automakers

The EV enterprises with the "new and high-tech" status are entitled to 15 percent rate of corporate income tax which is 10 percent lower than the legal rate.

Reward to charging infrastructure construction

Cities or city clusters with the certain number of EVs registered will receive fiscal reward for charging infrastructure construction. In Beijing-Tianjin-Hebei region, the Yangtze River delta region and the Pearl River delta region, cities or city clusters must register at least 2500 unit EVs (standard model) in 2013, at least 5000 in 2014, and at least 10000 in 2015. In other regions, cities or city clusters must register at least 1500 unit EVs (standard model) in 2013, at least 3000 in 2014, and at least 5000 in 2015. The number of EV applied is calculated on the standard model of BEV. The number of other types of EVs shall be calculated in accordance with the conversion coefficient to BEV. The reward standard is shown at Table 4. Reward fund will be used by local governments for operation and upgrade of charging infrastructure and construction of charging/battery swap stations. It shall not be used for subsidy to purchase EVs. Moreover, charging facilities to be rewarded shall comply with relevant national and industrial standards²¹.

¹⁹ The Ministry of Science and Technology, the Energy-Saving and New Energy Vehicle Major Project in the Eleventh Five-Year Succeed, 9 October, 2012, http://www.most.gov.cn/kjbgz/201210/t20121008_97083.htm

²⁰ Ministry of Science and Technology, Application Guide of Electric Vehicle Key Technology and System Integration Major Project (Phase I), 29 October, 2010,

²¹ The Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, the National Development and Reform Commission, Notice on Reward to Charging Infrastructure for New Energy Vehicles (Caijian [2014] No. 692), 18 November, 2014.

Table 4 Reward standards of EV charging infrastructure construction, 2013-2015

Region	2013		2014		2015	
	No. of EV registered (Q)	Reward standard (¥10000)	No. of EV registered (Q)	Reward standard (¥10000)	No. of EV registered (Q)	Reward standard (¥10000)
City or city cluster in Beijing-Tianjin-Hebei region, the Yangtze River delta region and the Pearl River delta region	$2500 \leq Q < 5000$	2000	$5000 \leq Q < 7000$	2700	$10000 \leq Q < 15000$	5000
	$5000 \leq Q < 7000$	3000	$7000 \leq Q < 10000$	3800	$15000 \leq Q < 20000$	7000
	$7000 \leq Q < 10000$	4500	$10000 \leq Q < 15000$	5500	$20000 \leq Q < 25000$	9000
	$Q \geq 10000$	7500	$Q \geq 15000$	9000	$Q \geq 25000$	12000
City or city cluster in other regions	$1500 \leq Q < 2500$	1000	$3000 \leq Q < 5000$	1800	$5000 \leq Q < 7000$	2400
	$2500 \leq Q < 5000$	2000	$5000 \leq Q < 7000$	2700	$7000 \leq Q < 10000$	3400
	$5000 \leq Q < 7000$	3000	$7000 \leq Q < 10000$	3800	$10000 \leq Q < 15000$	5000
	$Q \geq 7000$	5000	$Q \geq 10000$	6700	$Q \geq 15000$	8000

4.3 Demand-side policies and measures

Subsidies for purchasing EV

In September 2013, Chinese Ministry of Finance announced a long anticipated renewal of China's electric vehicle subsidies. Consumers who purchases EVs can get subsidies from government. The subsidies amount to 60,000 yuan for pure electric cars with a range over 250 km, and 50,000 yuan and 35,000 yuan for EVs with range over 150 km and 80 km, respectively. A restriction on the subsidy for low-speed electric vehicles was removed. Electric and Plug-in hybrid electric buses also received subsidies, depending on length. For buses over 50 m in length, EVs will receive 500,000 yuan, and PHEVs will receive 250,000 yuan. Shorter PHEV buses do not receive a subsidy; by EV buses over 8 m and 6 m will receive 400,000 and 300,000 yuan respectively²². Taking into consideration the scale effect and technological advance, the new subsidies will be reduced to 5% below the levels of 2013 in 2014, and 10% below the levels of 2013 in 2015.

Tax reduction for purchasing EVs

Purchasing BEVs, PHEVs and FCVs will be exempted from tax on vehicles and vessels. Due to lack of cylinder, purchasing BEVs and FCVs will not be imposed consumption tax. From January 1, 2012 to December 31, 2015, public bus companies can enjoy electric vehicle purchase tax exemption when purchasing electric buses. From September

²² The Ministry of Finance, the Ministry of Science and Technology, Notice on Continuing to Promote and Apply Electric Vehicles (Caijian [2013] No. 551), 29 September, 2013.

1, 2014 to the end of 2017, the government will waive the auto-purchase tax (up to 10%) for BEVs, PHEVs and FCVs²³.

Public procurement

In June 2014, the National Government Offices Administration announced a measure that electric cars make up at least 30 percent of government vehicle purchases by 2016. Central government ministries and agencies will take the lead on purchases of BEVs, PHEVs and FCVs. The ratio will be raised beyond 2016, when local provinces are required to meet the target. Electric sedans should cost no more than 180,000 yuan after subsidies.²⁴

Setting standards for electric vehicles

At present China has established a basically sound EV standard system with 78 published EV standards. Among them, 28 are the standard of the finished vehicle and general standards, 24 are standards of power battery and key assembly standards, 26 are standards of charging infrastructure standard. Even so, different EV enterprises understand differently these standards, which resulted in incompatible products. This may cause the waste of social resources. Standards should be further refined and unified.

China has cooperated with Germany in developing and publishing standards. China and Germany jointly promote standards on DC charging, charging interface, and communication protocol to become international standards.

4.4 Governance structure

In December 2013, the State Council approved Inter-Ministerial Joint Committee on Energy-Saving and New Energy Automobile Industry Development which is led by the MIIT and includes other 17 ministries, that is, the NDRC, the MOST, the MOF, the Ministry of Public Security, the Ministry of Environmental Protection, the Ministry of Housing and Urban-Rural Development (MHURD), the Ministry of Transport, the Ministry of Commerce, People's Bank of China, the State-Owned Assets Supervision and Administration Commission, the General Administration of Customs, the State Administration of Taxation, the General Administration of Quality Supervision, Inspection and Quarantine, China Banking Regulatory Commission, China Securities Regulatory Commission, China Insurance Regulatory Commission, the National Energy Administration (NEA). The members of the Committee are vice-ministerial level or higher officials²⁵.

The joint Committee will strengthen the macro guidance of the new-energy automotive industry, especially of the EV industry, facilitate the implementation of related policies, and coordinate in major issues regarding the industry development. The Committee has play an important role in resolving major obstacle to EV industry development. For

²³ The State Council, Guide Opinion on Speeding up Promotion and Application of New Energy Vehicles (Guobanfa [2014] No. 35), 21 July, 2014.

²⁴ the National Government Offices Administration, the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, the National Development and Reform Commission, Measure on Government Purchasing New Energy Vehicle (Guoguanjieneng [2014] No. 293), 11 June, 2014.

²⁵ The Ministry of Industry and Information Technology, Inter-Ministerial Joint Committee on Energy-Saving and New Energy Automobile Industry Development Held A Meeting, 8 December, 2014, <http://www.miit.gov.cn/n11293472/n11293832/n11293907/n12246780/16304187.html>

example, in order to speed up the construction of charging infrastructure, under the Committee, the MOF introduced a new award to EV charging infrastructure construction, the MHURD is formulating a plan of new energy automobile charging infrastructure, and the NEA is leading to develop the electric vehicle charging infrastructure development plan (2015-2020). The mechanism can avoid the conflict of policy measures of different ministries and improve the compatibility of policies.

5. Lessons learned

The development of EV industry in China adopts a top-down model and governmental interventions have played a significant role in this transition.

So far, the EV development in China adopts a top-down approach and is mainly driven by central government. Government is the initiator, driver and facilitator of the transition. Due to the high-risk, complexity, and long-term timeframe of EV development, without government the transition will not be started and success. Governmental interventions, covering R&D support, promotion pilot, tax credit for EV enterprises, and subsidy for personal purchasing EVs, have played a significant role in this transition.

A fledged policy framework covering both supply-side policies and demand-side policies is critical at the early stage of EV system transition.

The government has established a policy framework to accelerate electric-vehicle technology development, including policies and measures in supply side as well as those in demand side. Fostering an emerging industry and promoting a system transition need a systematic policy measures, meaning from supply-side policies to demand-side policies. The supply-side policies make auto enterprises be willing to develop, produce and improve EVs. The demand-side policies facilitate consumers to buy EVs even they are not as good as traditional cars in performance.

There should be a balance between government's role and market mechanism.

Government's interventions are important. But market mechanism should play its role. There should be a balance between these two mechanisms; otherwise the transition will not be successful. There is a trend that automakers rely too much on governmental subsidies. According to statistics, in 2013, 22 listed auto companies had received 5.59 billion yuan subsidies which grew 16% compared to 2012 and 100% to 2011. Many auto enterprises' profit comes from subsidies. But according to central government's plan, the subsidy policy will gradually exit after 2015. It is not a long-term solution that Chinese auto enterprises over rely on subsidy. Moreover, subsidy policy limits market mechanism playing its role. Policy makers should think over that policies could encourage auto enterprise to produce EVs, but at the same time let competition play role in EV market development.

Coordination between ministries should be strengthened to improve the transition.

System innovation such as EV development includes dozens of ministries which have different responsibility and role. The MIIT is responsible for leading the formulation of EV development plan, EV industry development policies and related standards. The SEA

is responsible for the development of EV charging infrastructure. the General Administration of Quality Supervision, Inspection and Quarantine (National Standard Committee) is responsible for leading formulation of national standards of EV and charging infrastructure. The MOST is responsible for support EV R&D by universities, public research institutes and enterprises. Hence better coordination between ministries is very significant for the transition.

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