Sweden-China Bridge

Collaborative Academic Platform for the
Electrification of Transportation Systems

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ELECTRIFICATION OF THE TRANSPORTATION SYSTEM IN CHINA

EXPLORING INDUCTIVE CHARGING TECHNOLOGY FOR ELECTRIC VEHICLES IN CHINA 1.0

Title: Exploring Inductive Technology For Electric Vehicles In China 1.0

Authors: Jasmine Lihua Liu[1, 2, 3], Shendong Zu[2] & Mike Danilovic[1, 2, 4].

[1]Lund University, Sweden; [2]Shanghai Dianji University, China; [3]Jönköping University, Jönköping International Business School, Sweden; [4]Halmstad University, Sweden.

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In cooperation with Tomas Müllern [5], Arne Nåbo [6] & Philip Almestrand Linné [6].

[5]Jönköping University, Jönköping International Business School, Sweden.

[6]Swedish National Road and Transport Research Institute, Sweden.

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ABOUT THE SWEDEN-CHINA BRIDGE PROJECT

This project funded by The Swedish Trafikverket (TRV), formally started the 1st of September 2020, and will last until the end of 2022.

Exploratory approach

This project is exploratory in nature and includes a step-by-step approach to knowledge development in the Swedish and the Chinese context. The project spans different areas of knowledge in which we will highlight what technologies and systems are prioritized in China, Sweden and in Europe, what drivers and motives exists for them, what actors are involved in the transition to electrified, intelligent and integrated transport systems, and what conditions and business models look like to achieve this conversion to electrified and integrated transport systems in an intelligent and smart society.

The purposes of the Sweden-China Bridge Project

1. The project aims to establish and develop an academic knowledge-sharing and -transfer platform between Sweden and China for collaboration between universities and research institutes in the two countries, in order to contribute to increased understanding and information and knowledge sharing on the technical and commercial development of electrified vehicle systems, integrated transport system solutions, and energy supply infrastructure as a fully integrated system of intelligent and smart cities.

2. From this perspective, the project will explore the development and implementation of relevant technology for the electrification of vehicles, such as fuel cells, bio energy, battery storage, combinations of energy systems for hybrid vehicles, energy supply for integrated electrified vehicles, integrated electric road technology, associated charging infrastructure, and static and dynamic technology.

3. We also intend to explore the management of renewable energy supply systems, from the production of renewable electricity to its distribution to consumers of electrified transport systems, which is needed to ensure that electrified vehicles and transport systems.

Expected value creation

1. To create insights into the current and future status of electrification of transportation systems in Sweden and in China from technical, social, societal and economic perspectives.

2. To learn and mutually develop insights into how new knowledge, technology, system-based solutions, logistics and transportation systems can be developed, commercialized and operated according to a life cycle perspective in both Sweden and China.

3. To create a long-term learning context in which Sweden and China exchange experience for the benefit of both countries and their industries.

4. To develop a deeper understanding of how Sweden and China are managing the large-scale electrification of the road network using different technologies, including electric charging, energy production (fuel cells, hybrid vehicles, battery storage and electric roads): what do the short- and long-term potentials look like? How are they using long-term industry policy instruments to develop technology and implement it in society? How are they outlining business models for the large-scale roll-out of electrified transportation systems?

Research team

Mike Danilovic
Ph.D., Project leader, Professor, Halmstad University, Sweden & Distinguished Overseas Professor at Shanghai Dianji University Shanghai, China.
Affiliated researcher at Lund University, Sweden.

Tomas Müllern
Ph.D., Professor, Jönköping University, Jönköping International Business School, Sweden.

Jasmine Lihua Liu (刘莉华)
Ph.D., Senior researcher at CIRCLE, Lund University, Shanghai Dianji University, China. & Affiliated researcher at MMTC, Jönköping University, International Business School, Sweden.

Arne Nåbo
Tech. lic., Research director, Swedish National Road and Transport Research Institute (VTI), Sweden.

Jeanette Andersson
Ph.D., Researcher, Swedish National Road and Transport Research Institute (VTI), Sweden.

Philip Almestrand Linné
Ph.D., Researcher, Swedish National Road and Transport Research Institute (VTI), Sweden.

Wang Junhua
Ph.D., Professor, Tongji University, Shanghai, China.

Liu Shuo
Ph.D., Assistant Professor, Tongji University, Shanghai, China.

Qiu Xiaoping
Ph.D., Professor, Southwest Jiatong University, Chengdu, China.

Susan Lijiang Sun
Ph.D., Professor, Shanghai Dianji University, Shanghai, China.

Ma Hongwei
Ph.D., Associate Professor, Shanghai Dianji University, China.

Academic partners in China

China Electric Power Research Institute (CEPRI), Beijing, China.

Zhejiang University, Deqing Research Center, Institute of Artificial Intelligence, Hangzhou, China.

Urban and Rural Construction and Transportation Development Research Institute, China.

Industrial partners in China

Beijing
Scania China Innovation Center, Beijing, China.

Shanghai
Shanghai Power Keeper, Shanghai, China.
Shanghai Jiulong Power, Shanghai, China.
Zhejiang VIE-Evatran Electronic Technologies Co., Ltd., Shanghai, China.
BYD, Shanghai, China.

Shenzhen
DST, Shenzhen, China.
Xieli innovation Center, Shenzhen, China.
Shenzhen Bus Group, Shenzhen, China.
Shenzhen Electric Vehicle Application and Promotion Center, Shenzhen, China.
Potevio New Energy, Shenzhen, China.
Haylion, Shenzhen, China.
Guangzhou Bus Group, Guangzhou, China.

Contact

Mike Danilovic, Ph.D.
Professor of Industrial Management Innovation and Technology Management.

Halmstad University
P O Box 823
SE18 301 HALMSTAD
SWEDEN

Phone:
+46708157588 (Sweden) I +8613761129945 (China)

E-mail:
mike.danilovic@hh.se

Visiting professor:
Distinguished Overseas Professor at Shanghai Dianji University Shanghai, China.
Affiliated researcher at Lund University, Sweden.

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As project leader, I am grateful to my research fellows and colleagues in this project: Dr. Jasmine Lihua Liu, Professor Tomas Müllern, Tech.lic. Arne Nåbo, and Dr. Philip Almestrand-Linné.

I thank you all from the bottom of my heart.

Professor Mike Danilovic, on the behalf of the entire research team.

ABSTRACT

In 2020, there were about 360 million vehicles in China, of which 270 million were passenger vehicles, accounting for 75% of the total number of motor vehicles, while the new energy vehicle population was 4.17 million, a year-on-year increase of 9.45%. According to the forecast of the State Grid Electric Vehicle Company, the number of electric vehicles in China will reach 300 million in 2040.

This article mainly conducts research in the field of wireless power transmission for static and dynamic charging of electric vehicles in China.

The orderly guidance of electric vehicle charging can greatly increase the utilization rate of grid equipment and save nearly 70% of investment. The power battery capacity can reach more than 20 billion kWh, which will provide 12 billion kWh of energy storage and 4.8 million MW of regulation capacity for the grid.

There are several Chinese automotive OEM companies, such as FAW, SAIC, Geely, Changan, Dongfeng, BAIC, GAC, BYD, etc., all of which are involved in the development of wireless charging technology, as well as several independent equipment companies. There are also more than 30 electric vehicle wireless charging equipment suppliers in China, including Xiamen New Page, ZTE New Energy, Huawei Technology, Wanan, Anjie, and Zhonghui.

Some interesting achievements of some of the Chinese companies include:

- SAIC Roewe released the pure electric SUV MAVELX in 2018, equipped with a 6.6 kW EV WPT (wireless power transfer) system. The model is also equipped with the AI Pilot intelligent driving assistance system, which has the AI Parking full-function intelligent parking assistance system, offering the perfect combination of automatic parking and EV WPT. The wireless charging system configured by MAVELX is a front-end product. The vehicle chassis retains the structure, electrical and communication interfaces for the EV WPT. This is the first pure electric vehicle equipped with EV WPT.
- ZXNE is a wholly owned subsidiary of ZTE Corporation. It began researching EV WPT technology in 2012 and established an operating company in July 2014. As of August 2019, ZXNE had completed the development of the third-generation EV WPT system. The first-generation products are put in operation. In 2016, it has completed modification and testing with 11 domestic and foreign auto manufacturers.

The development in demonstration sites began in 2015, based on the early days of research and basic technology development. The foundation has led to mature knowledge and a theoretical framework for the operation of wireless charging technologies.

In 2015, EV WPT's TRL (Technology Readiness Level) curve reached TRL6 in the private domain due to the early mature theoretical system. Since 2019, the development of EV WPT in the private sector has become more mature, and the curve will reach TRL7 in 2020.

In the public application field, a large amount of theoretical knowledge about the application results of WPT on the TRL reached L3 in 2010 and rose to TRL6 in 2019.

There are two main reasons why TRL analysis does not show higher levels:

- There is a lack of national and international standards, particularly in interoperability, preventing the wireless charging technology from going all the way to full scale commercialization.
- There is also uncertainty concerning radiation associated with wireless charging. The sender and the receiver modules are physically separated and the distance between must be overcome with high energy transmission that creates radiation outside the ray beam between the sender and the receiver. It is unclear what outcome this radiation might have on humans and animals. Until this is clear, full-scale commercialization has been put on hold.

Keywords: EV WPT; policies and standards; development status; TRL; forecasts and challenges.

OUTLINE OF THE PAPER

This paper consists of six main parts:

Part one
Introduction

In this part we introduce wireless charging technology as a complementary solution to the charging infrastructure required to enable electric vehicles to operate and grow to the large extent expected in the Chinese context.

Part two
Standards and policies

Here we elaborate on the development of standards, regulations and policies for the development of wireless technology and for the commercialization of systems based on wireless charging. We also discuss the subsidiary policy being applied to support the development and diffusion of wireless charging.

Part three
Development of wireless charging technology in China

In this part we discuss the sources of technology development, the research university teams and industry, and vehicle and equipment OEM-based research and development required to make wireless charging a working system. Here we also reflect on the differences in the private and the public domains for wireless charging and demonstration sites.

Part four
TRL analysis of wireless inductive charging development in China

In this section we analyze hydrogen technology development using the Technology Readiness Level (TRL) approach, showing the speed of development of key technologies needed for the hydrogen energy commercialization and practices.

Part five
Analysis

Here we analyze the development of wireless charging technology following the two main routes: the private and the public. We show that there is a time gap in the commercialization of wireless charging in those two domains of 5-10 years.

Part six
Conclusion

In this final part we draw some main conclusions on the technology development and the requirements that must be met to make wireless charging a sustainable system solution in China.

RESEARCH METHODOLOGY

The research for the Sweden-China Bridge project is based on primary data from company visits, observations, and interviews, and through the collection of secondary data in English and in Chinese. One senior research team member, Dr. Jasmine Lihua Liu, is of Chinese origin and thus we were able to cover this area from Chinese perspectives, both in respect of a literature search and from the point of view of a deeper understanding of the societal, cultural, and contextual environment as it pertains to the process of electrification of transportation in China. To deepen our understanding further still, we followed a variety of discussions in different webinars, conferences, and among experts.

Dr. Liu is an experienced researcher in both the Swedish and Chinese contexts of transformation towards renewable energy. She received her PhD in Innovation Sciences from Halmstad University in 2019 and is thus well oriented in the Swedish context. Mr. Shengdong Zu is a researcher at Shanghai Dianji University and member of a local research team consisting of Mr. Ran Dong, Mr. Xiang Chen, and Mr. Shengdong Zu, under the lead of Professor Susan Lijiang Sun. In the Chinese context, the research underlining this report was undertaken in 2020 as desktop-based research. Mr. Shengdong Zu was the main data collector and the main co-author of this report.

In October-December 2020 part of the research team travelled to China where they visited corporate organizations, leading institutions, and leading academic institutes in Beijing, Shanghai, and Shenzhen, and carried out observations and personal interviews with people in the research area of the electrification of transport systems in China.

During December 2020, in one intensive week, we conducted company visits, discussions and formal interviews with key players in the electrification of Shenzhen city in southern China. This working week was a joint collaborative venture with the Scania China Innovation team in Beijing. The information collected during this intensive period in China will be elaborated on in forthcoming papers on electrification technology development and research into the electrification of Shenzhen as the only city in the world to have achieved 100% electric taxis, buses and most of its intra-city-based logistics and working vehicles.

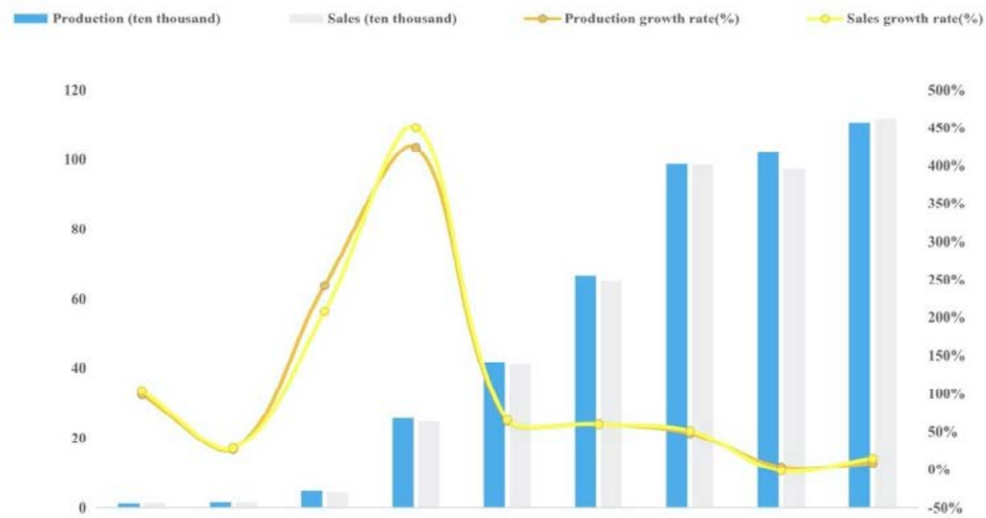
In May 2021, we collaborated with the Scania China Innovation team through corporate visits to several Chinese battery-swapping developers and operators to jointly explore the role of battery-swapping for heavy vehicles, such as trucks.

In April-June 2021, we conducted several seminars in Sweden with participants from academia and industry to share our observations and listen to questions on electrification of transport in China in general, and on battery-swapping. This dynamics in our research creates awareness and mutual learning based on our ongoing research on electrification of transport in the Chinese context.

PART ONE
INTRODUCTION

In the 21st century, China has established a system of policies and regulations to promote the transition to a low-carbon economy for the government, enterprises, and citizens. At the same time, the Chinese government proposed that the development direction of the automobile industry should be consistent with the development direction of the low-carbon economy. China is now vigorously advocating the development of a low-carbon economy, and at the same time is in a period of transitioning transportation and energy from fossil based to renewable energy, from internal combustion engines (ICE) operating on fossil fuels to electric vehicles. To achieve the leap from major automobile production based on old technologies, China has taken steps to develop into a technologically driven country, based on modern automotive technology. To achieve this transformation, the chosen path is based on clean energy production and clean emissions from the transport industry, energy diversification to satisfy different conditions, and the development of complementary solutions and power electrification of the transport industry.

According to the forecast data of China's State Grid Electric Vehicle Company, the number of electric vehicles in China will reach 300 million by 2040.



	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production (ten thousand)	1. 12	1. 42	4. 86	25. 46	41. 70	66. 60	98. 60	102. 00	110. 50
Sales (ten thousand)	1. 14	1. 46	4. 50	24. 75	40. 90	65. 20	98. 40	97. 20	111. 50
Production growth rate (%)	98. 80%	26. 79%	242. 25%	423. 87%	63. 79%	59. 71%	47. 90%	3. 40%	8. 33%
Sales growth rate (%)	103. 90%	28. 07%	208. 22%	450. 00%	65. 25%	59. 41%	50. 80%	−1. 20%	14. 71%

Figure 1: China's EV production and sales, and growth rate
Source: China Association of Automobile Manufacturers (www.caam.org.cn/) [1]

The orderly guidance of electric vehicle charging can greatly increase the utilization rate of grid equipment and save nearly 70% of investment. The power battery capacity can reach more than 20 billion kWh, which will provide 12 billion kWh of energy storage and 4.8 million MW of regulation capacity for the grid[1]. China's national motor vehicle ownership in 2020 is 360 million, of which 270 million are cars, accounting for 75% of the total number of motor vehicles, and the new energy vehicle population is 4.17 million, a year-on-year increase of 9.45%.[2]

Although the development of electric vehicles has been strongly supported by many countries and automobile companies have taken big steps towards developing new energy vehicles, compared with ICE and fossil-based fuel vehicles, electric vehicles are facing challenges, such as charging infrastructure and charging facilities, long charging times, particularly for heavy trucks and buses, and the need for large battery capacity to ensure reasonable operational ranges. These challenges are, to a large extent, affecting the promotion and popularization of electric vehicles among the public and businesses alike.

To solve the problems of long charging time and the general inconvenience associated with charging electric vehicle (EV) batteries, the focus has been on wireless power transmission technology (hereinafter referred to as EV WPT), enabling vehicles to charge batteries while idling (static charging) or running on the roads (dynamic charging). The EV WPT technology can effectively solve the interface limitations faced by traditional and dominant cable-based charging.

The EV WPT system is either laid on or built into the road and combined with public facilities to continuously provide energy power for electric vehicles in a wireless, non-contact manner, realizing a convenient and intelligent charging method. However, one main challenge with wireless charging is interoperability, whereby different brands of vehicles can use the wireless charging of any brand or supplier. This requires technical standardization and unification of operational standards.

The basic principle of the EV WPT system uses the principle of electromagnetic induction, transmitting the energy from the sender's coil to the receiving coil under the vehicle, and then charging the battery pack. This method, when widely introduced, can greatly reduce the battery size and capacity, and thus the total vehicle price, and expand the scope of application of electric vehicles. Inductive technology is not new. Many new items of household equipment operate on inductive technology, as well as wireless charging of smart phones. The main difference to wireless charging of vehicles is the energy volumes being transmitted and the challenges of transmitting energy while driving, i.e. dynamic charging.

Another challenge to wireless charging systems is how to handle the radiation from the sender while in transmitting energy outside of the vehicle, and its possible impact on people and animals.

PART TWO
STANDARDS AND POLICIES

China's national and local standards

China national standard

The "Electric Vehicle Wireless Charging System" series of standards have formulated against a background that sees China's new energy vehicle industrialization process accelerating, and new energy vehicles, mainly electric vehicles, increasing in volume, and a variation of needs in the high density and populated cities, large and distributed city areas, and long intercity distances. All have different needs to be solved, not with one but with several complementary solutions, while the speed of growth in the volume of electric vehicles necessitates urgent solutions for charging infrastructure.

China has developed several complementary charging infrastructure solutions, such as cable-based charging, battery-swapping, and the wireless charging systems. Each of these has different characteristics and functionality, advantages, and disadvantages. No solution is perfect and there are strong arguments for developing complementary system solutions.

Wireless charging technology uses the principle of near-field magnetic coupling to charge electric vehicles through space transmission. It will be one of the important charging technologies for electric vehicles over the next 20 years.

Since the wireless charging system realizes the transmission of electric energy from the grid to the electrical equipment through non-physical contact, the electric vehicle wireless charging system is embodied in the transmission of electric energy from the ground to the vehicle, so there are electrical, communication, and magnetic circuits on the ground and in the vehicle; these and other intangible "interfaces" require regulatory standards.

To this end, the China Electricity Council and the China Automotive Technology and Research Center jointly organized the development of the "Electric Vehicle Wireless Charging" standard system. [3] The system of standards for wireless charging initially planned 14 and later adjusted and planned 18 national standards to standardize the technical requirements, performance requirements, functional requirements, safety requirements, communication protocols, and testing of electric vehicle wireless charging systems in public and private applications. These include requirements and test methods, interoperability requirements and test methods, construction acceptance, operation, and maintenance, etc.

On 1 November 2020, the National Standards Committee announced four of these national standards, and four other national standards are in the process of preparation. Among those standards, Part 1 to Part 4 is intended to meet the key standards of the private application field. The implementation of these four national standards has promoted the rapid development of WPT in the private application field and provided corresponding standards for car manufacturers and product development teams.

The specific standards are shown in **Table 1**:

No.	Standard Name	Standard Number	Status
1	Electric vehicle wireless power transfer. **Part 1:** General requirements.	GB/T 38775.1-2020	In force
2	Electric vehicle wireless power transfer. **Part 2**: Communication protocols between on-board charger and wireless power transfer device.	GB/T 38775.2-2020	In force
3	Electric vehicle wireless power transfer. **Part 3:** Specific requirements.	GB/T 38775.3-2020	In force
4	Electric vehicle wireless power transfer. **Part 4:** Limits and test methods of electromagnetic environment.	GB/T 38775.4-2020	In force
5	Electric vehicle wireless power transfer. **Part 5:** Electromagnetic compatibility requirements and test methods for electric vehicle wireless power transfer systems.		In progress
6	Electric vehicle wireless power transfer. **Part 6:** Interoperability requirements and testing ground assembly.		In progress
7	Electric vehicle wireless power transfer. **Part 7:** Safety and interoperability requirements of magnetic field wireless power transfer for electrically propelled vehicles.		In progress
8	Electric vehicle wireless power transfer. **Part 8:** Specific requirements for commercial vehicles.		In progress

Table 1: Progress of China's EV WPT standards

Source: China Standardization Administration (www.sac.gov.cn/) [4-7]

It is expected that in the next one to two years (2022-2023), wireless charging products for private electric vehicles (passenger vehicles) will be put on the market.

Parts 5 to 8 are the key standards in the public application field. The standards of these parts are in the formulation stage, and related products are still in the experimental stage. It is expected that after the implementation of these four standards, the design and development of electrified roads will advance rapidly.

The first batch of announcements of the four national standards – including the general requirements, the communication protocol between on-board chargers and charging equipment, and special requirements – are important basic general standards in the wireless charging standard system for electric vehicles. The communication requirements and special requirements stipulate the power transmission and system function-related requirements that need to be followed during product design and product testing of the electric vehicle wireless charging system, and give clear baseline requirements for performance indicators, safety indicators, and functional indicators.

The test methods requirements form the guiding and normative actions for product design and testing; the communication protocol regulates the specific procedures, parameters and data definitions of wireless charging, etc., and gives the minimum communication protocol architecture for the power transmission system; electromagnetic environment limits and test methods provide electromagnetic pipe diameter exposure limits, and electromagnetic environment test and evaluation methods for components and wireless charging systems installed in vehicles.

The first batch of announcements of the "Electric Vehicle Wireless Charging System" series of national standards filled the gaps in China's national standards and specifications in the field of electric vehicle wireless charging technology, improved the standard system for electric vehicle wireless charging, and proposed system performance, safety, and functions.

Clear requirements and test methods support the development, testing and application of wireless charging system products in private applications. The release of this series of standards is a milestone in promoting the development of China's electric vehicle wireless charging industrialization process, enriching its electric vehicle charging technology system and application scenarios, and playing the lead role of standards in technology.

The second batch of announcements of the "Electric Vehicle Wireless Charging System" series of national standards has promoted another milestone in the development of China's electric vehicles on electrified roads. It has formulated the key technologies for electrified roads: electrical, magnetic, communication, safety, and functional components interoperability. It indicates that product development, testing and application have practical value in the field of public applications.

Chinese local standards

Guangdong Province in the south of China is at the forefront of China's electric vehicle wireless charging technology industry. The Guangdong Electric Vehicle Standardization Technical Committee issued 10 local standards for electric vehicle wireless charging systems on 2 January 2018[4] and 2 April 2018. Those specific standards are shown in **Table 2**:

No.	Standard Name	Standard Number	Status
1	Electric vehicle wireless power transfer. **Part 1:** General Requirements	DB44/T 2099.1-2018	In force
2	Electric vehicle wireless charging system. **Part 2:** Communication Protocol	DB44/T 2099.2-2018	In force
3	Electric vehicle wireless charging system. **Part 3:** Magnetic Coupling	DB44/T 2099.3-2018	In force
4	Electric vehicle wireless charging system. **Part 4:** Interface	DB44/T 2099.4-2018	In force
5	Electric vehicle wireless charging system. **Part 5:** Safety	DB44/T 2099.5-2018	In force
6	Electric vehicle wireless charging system. **Part 6:** Management System	DB44/T 2099.6-2018	In force
7	Electric vehicle wireless charging system. **Part 7:** Electricity Measurement Requirements	DB44/T 2099.7-2018	In force
8	Electric vehicle wireless charging system. **Part 8:** Ground Facilities	DB44/T 2099.8-2018	In force
9	Electric vehicle wireless charging system. **Part 9:** Vehicle Equipment	DB44/T 2099.9-2018	In force
10	Electric vehicle wireless charging system. **Part 10:** Charging Station	DB44/T 2099.10-2018	In force

Table 2: Local standards for wireless charging of electric vehicles in Guangdong Province
Source: Guangdong Electric Vehicle Standardization Technical Administration (www. sac.gov.cn/) [9-18]

Scope of technical standards application areas

Part 1 specifies the classification, interoperability requirements, overall system requirements, communication requirements, electric shock protection requirements, safety requirements, structural requirements, strength of materials and components, test condition requirements, electromagnetic compatibility, and marking of electric vehicle wireless charging systems and description, etc. This section is applicable to static magnetic coupling electric vehicle wireless charging systems. The maximum rated voltage of the power supply is 1000V AC or 1500V DC, and the maximum rated output voltage is 1000V AC or 1500V DC.

Part 2 specifies the communication protocol application layer for management and control between the electric vehicle communication control unit and the wireless charging control management system, the ground communication control unit and the wireless charging control management system, as well as the ground communication control unit and the vehicle communication control unit. This section applies to the management and control between the electric vehicle on-board communication control unit and the wireless charging control management system, between the ground communication control unit and the wireless charging control management system, and between the ground communication control unit and the on-board communication control unit.

Part 3 specifies the characteristics and working conditions of the magnetic field wireless charging system, electrical safety requirements, power level requirements, alignment requirements, and electromagnetic compatibility requirements. This section applies to devices that use magnetic coupling to wirelessly charge electric vehicles.

Part 4 specifies the interface requirements for primary and secondary devices of the electric vehicle wireless charging system, communication interface requirements, power receiver (PPC) and electric vehicle power battery management system (BMS), and battery interface requirements and positioning auxiliary equipment interface requirements. This section applies to the relevant interfaces of the charging equipment of the electric vehicle wireless charging system.

Part 5 specifies the communication safety, electrical safety, mechanical safety, lightning protection and electromagnetic field radiation of the electric vehicle wireless charging system. This section is suitable for scenarios where the ground communication control unit, on-board communication control unit and wireless charging control management system belong to the same charging operator.

Part 6 specifies the functional requirements of the operation and maintenance monitoring management, business operation management, system management and the technical requirements of the electric vehicle wireless charging control management system (hereinafter referred to as the management system or WCCMS). This section applies to the wireless charging control management system of electric vehicles.

Part 7 specifies the configuration and installation requirements and technical requirements of the electric energy metering device for the measurement of electric vehicle wireless charging systems, as well as the technical requirements for the measurement of charging systems. This section applies to the electric energy measurement requirements of the wireless charging system of electric vehicles.

Part 8 specifies the conditions of use, technical requirements, inspection and testing, marking, packaging and storage requirements for ground facilities of the electric vehicle wireless charging system. This section applies to the configuration and acceptance of wireless charging ground equipment using magnetic coupling, as well as to new expansion and reconstruction projects of electric vehicle wireless charging facilities.

Part 9 specifies the technical requirements, inspection rules, test methods, markings, packaging, storage, and transportation requirements of on-board equipment for electric vehicle wireless charging systems. This section applies to the configuration and acceptance of wireless charging on-board equipment using magnetic coupling, production, and modification of electric vehicles for wireless charging.

Part 10 specifies the power supply system, charging system, monitoring system, electric energy measurement, communication system and protection requirements of the charging station of the electric vehicle wireless charging system. This section applies to the design and construction of charging stations for wireless charging systems for electric vehicles.

China's policy

Development policy

On 20 October 2020, the General Office of the State Council of China issued the New Energy Automobile Industry Development Plan (2021-2035),[20] which pointed out that it is necessary to vigorously promote the construction of charging infrastructure and battery-swapping systems and networks and speed up the construction and diffusion of charging and battery-swapping infrastructure.

The policy intends to accelerate the formation of an advanced, public charging infrastructure and network with the fast cable-based charging mode as the main thrust, and slow vehicle charging as a complementary supplement. It is also intended to encourage the application of battery-swapping modes and strengthen the research and development of new charging technologies, such as intelligent and orderly charging, high-power charging, and wireless charging to enhance the convenience and reliability of charging.

Subsidy policy

On 1 January 1 2021, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the Development and Reform Commission jointly issued the "Notice of the Ministry of Finance, Ministry of Industry and Information Technology, Ministry of Science and Technology Development and Reform Commission on Further Improving the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles" (Caijian, 2020,) No. 593, hereinafter referred to as "Notice").[21]

This notice pointed out that: Since 2009, the Ministry of Finance and relevant departments have strongly supported the development of the new energy automobile industry. With the joint efforts of all parties, China's new energy vehicle technology level has continuously improved, product performance has been significantly improved, and the scale of production and sales has ranked first in the world for five consecutive years.

At the beginning of 2020, affected by multiple factors, China's new energy vehicle market declined. To support the high-quality development of the new energy vehicle industry and promote the consumption of new energy vehicles, the four ministries and commissions jointly issued the "Notice on Improving the Fiscal Subsidy Policy for the Promotion and Application of New Energy Vehicles" (Caijian, 2020, No. 86).

In April 2020, the implementation period of the new energy vehicle promotion and application of the fiscal subsidy policy was extended to the end of 2022, and the decline in subsidies for the purchase of new energy vehicles in 2021 and 2022 has been clarified in advance to stabilize market expectations.

Driven by the steady recovery of economic growth and the support of relevant policies, China's new energy vehicle market has bottomed out from the second quarter. A total of 1,109 million vehicles were sold from January to November, a year-on-year increase of 3.9%. In order to further promote the healthy and orderly development of the new energy vehicle industry, in accordance with the relevant provisions of the Caijian (2020) No. 86 document, the four ministries and commissions have recently jointly issued the "Notice", which further clarifies the relevant requirements of the fiscal subsidy policy for the promotion and application of new energy vehicles in 2021.

Regarding the new energy vehicle purchase subsidy standard in 2021. According to the Caijian (2020) No. 86 document, the new energy vehicle purchase subsidy standard in 2021 will be reduced by 20% on the basis of 2020; in order to accelerate the electrification of vehicles in public transportation and other fields, urban New energy vehicles that meet the requirements in public transportation, road passenger transportation, rental (including online car-hailing), environmental sanitation, urban logistics and distribution, postal express, civil aviation, airport, and party and government agencies will be reduced by 10% in 2021 on the basis of 2020.

According to this, the "Notice" clarified the subsidy standards for different types and fields of vehicle products, providing a basis for the precise implementation of subsidy policies. Considering that the relevant decline rate has been issued in advance through Caijian (2020) No. 86 document, the above standards will be implemented from 1 January 2021.

PART THREE
DEVELOPMENT OF WIRELESS CHARGING TECHNOLOGY IN CHINA

Chinese university team

Research on EV WPT in China is relatively new, but as the concept of environmental protection and sustainable development become more mature and more important, EV WPT has also received more attention from politicians, universities, and industry.

The following table lists the major research status of the EV WPT technology carried by the Chinese university research team:

No.	Research universities and teams	Research content and development	Time
1	Professor Hui Yi Hui, City University of Hong Kong	Research on the Application of Low Power WPT Technology in Consumer Electronic Products.	1990s
2	Professor Sun Yue, Chongqing University	In 2002, he conducted research on WPT technology and formed a comprehensive theoretical system of circuit topology, control strategy, magnetic circuit design, system modeling and participation, data optimization, etc. Research results have been achieved in the fields of household appliances, drilling, and construction. Good application demonstration effect.	In 2002
3	Professor Huang Xueliang from Southeast University, Professor Zhu Chunbo from Harbin Institute of Technology, Professor Yang Qingxin from Tianjin Polytechnic University, Professor Zhao Zhengming from Tsinghua University, Professors Wang Lifang and Chen Qianhong from Nanjing University of Aeronautics and Astronautics, etc.	The formation of a WPT technology research team has greatly promoted the research process of WPT theory and technology in China and formed a complete theoretical system that can support industrial applications.	In 2007
4	Professor Sun Yue, Chongqing University	The first dynamic wireless charging demonstration system.	In 2015
5	Professor Sun Yue, Chongqing University	Completion of the second set of dynamic wireless charging system demonstration in conjunction with unmanned vehicles in Jiangsu Province.	In 2019

Table 3: Research on EV WPT by Chinese university team
Source: Electric vehicle wireless charging applications and development trends [19]

We are aware that research on inductive charging is conducted at many universities across China and among several national and regional institutes.

Table 3 indicates the most important research entities and research teams.

EV companies

With the formulation of interoperability-related standards in China and internationally, the continuous development of intelligent networking of electric vehicles, and the approaching time for commercial applications, mainstream Chinese and international automotive companies have increasingly urgent demands for intelligent wireless charging technology. Currently, vehicles with wireless charging capabilities are products suitable for the private application field, but are not interoperable across different brands.

Mainstream Chinese automotive companies such as FAW, SAIC, Geely, Changan, Dongfeng, BAIC, GAC, BYD, etc. are all involved in the development of wireless charging technology directed in the first place towards the private domain.

There are several reasons for the focus on private passenger vehicles. Wireless charging for heavy duty trucks and buses is more complex due to the distance between the sending coils in the road and the receiving coils under the vehicle. The longer the distance, the greater the amount of energy that needs to be transmitted. In addition, dynamic charging is places high demands on continuation of the sending/receiving process, without interruptions. The lack of international standards, and questions regarding radiation are some of the key challenges that wireless charging technology is facing.

Equipment manufacturers

With the continuous development of EV WPT technology and the increasing demand from car companies, equipment manufacturers have entered the EV WPT arena to jointly promote the development of the wireless charging technology, systems, and industry.

At present, there are more than 30 electric vehicle wireless charging equipment suppliers in China, including Xiamen New Page, ZTE New Energy, Huawei Technology, Wanan, Anjie, Zhonghui, BYD, and other wireless technology charging companies. Internationally, wireless charging has received attention from industry in Israel, USA, and Europe.

Equipment manufacturers in the EV WPT industry can be divided into two categories. The first is standard technology; a typical company is Huawei Technology. The second category is product manufacturing and systems integration; typical companies are Zhongxing New Energy Automobile Co. Ltd and BYD.

Illustration

SAIC Roewe released the pure electric SUV MAVELX in 2018, equipped with a 6.6 kW EV WPT system. The model is also equipped with the AI Pilot intelligent driving assistance system, which has the AI Parking full-function intelligent parking assistance system, providing the perfect combination of automatic parking and EV WPT. The wireless charging system configured by MAVELX is a front-end product. The vehicle chassis retains the structure, electrical and communication interfaces for the EV WPT. This is the first pure electric vehicle equipped with EV WPT.

ZXNE is a wholly owned subsidiary of ZTE Corporation. It began researching EV WPT technology in 2012 and established an operating company in July 2014. As of August 2019, ZXNE had completed the development of the third-generation EV WPT system. The first-generation products are put into operations. In 2016, it completed modification and testing with 11 domestic and foreign automakers. The second-generation products are used in China. In the pre-installation development of a certain automobile company, the third-generation product supports the technical route of domestic interoperability standards and conforms to one primary side device and nine secondary side devices. In the test conducted by the domestic standards organization in July 2019, the full power output within the Z value and offset range was achieved, and the system efficiency in the half load, full load and full offset range was 89% to 93% (the efficiency at full load is greater than 90%).

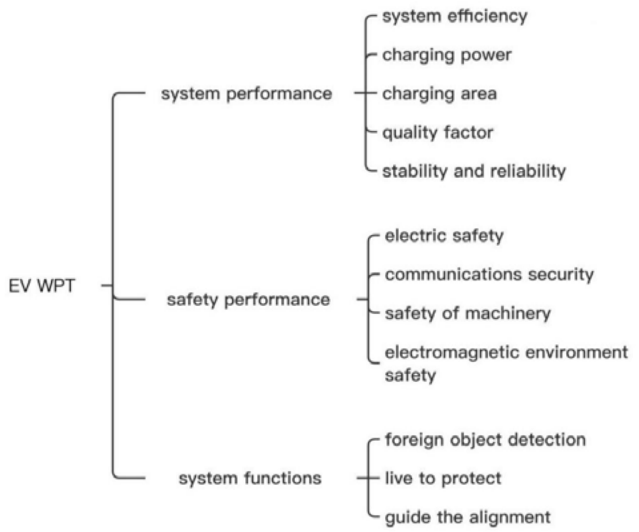


Figure 2: Demand for EV WPT in the private field
Source: Electric vehicle wireless charging applications and development trends [19]

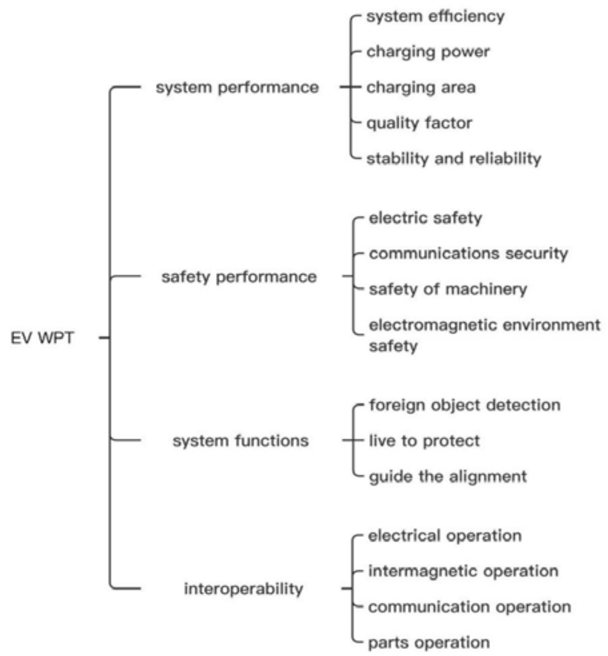


Figure 3: Demand for EV WPT in the public field
Source: Electric vehicle wireless charging applications and development trends [19]

As the relevant national standards for dynamic wireless charging are still in the formulation stage, the realization of electrified roads will take more time, but domestic experiments on electrified roads are ongoing.

Experimental sites for wireless charging

The Chinese development of wireless charging goes back to the end of the 1990s. By 2015 Chinese actors had initiated early real-life wireless charging development on demonstration sites.

In 2015, Chongqing University and Guangxi Electric Power Research Institute cooperated to build the first domestic electric vehicle dynamic wireless charging demonstration line in Guangxi. The length of the line is 100m, the maximum output power of the system is 30 kW, and the traveling power efficiency can reach 75%. In 2016, the China Electric Power Research Institute built a 200m-long dynamic wireless charging system for public transport in Zhangbei, Hebei. The system has a single module power of 20 kW, a dual module power of 40 kW, a wireless charging distance of 21cm, and a system efficiency of more than 70%. It is China's first dynamic wireless charging demonstration system for buses.

In 2018, Chongqing University and the State Grid Corporation of China established a dynamic wireless charging demonstration line in Tongli City, Jiangsu Province, which combined the operation of autonomous vehicles. The output power of the system is 11 kW, and the length of the demonstration line is 400m.

There have been plans to establish new test demonstration sites of up to 42 kilometers drive but Covid-19 in 2020 stopped those demonstration sites from being established.

Figure 4: Dynamic wireless charging system constructed by Chongqing University
Source: Electric vehicle wireless charging applications and development trends [19]

PART FOUR

TRL ANALYSIS OF WIRELESS INDUCTIVE CHARGING DEVELOPMENT IN CHINA

Currently, the TRL (Technical Readiness Level) analysis of China's EV WPT technology is shown in **Figure 5**, where it is clear that WPT technology is divided into two curves:

- A represents the development of EV WPT's TRL in the private application field over time.
- B represents the development of EV WPT's TRL in the public application field over time.

Figure 5: TRL development of China's EV WPT technology
Edited and drawn by Shengdong Zu

As shown in **Figure 3**, in the field of WPT private application, China did not focus on electric vehicles before 2015. The development in demonstration sites started in 2015, based on the early days of research and basic technology development. Since this foundation, the knowledge has matured along with the theoretical framework for operations of wireless charging technologies.

Since 2015, as electric vehicles have received more attention, some scientific research teams have turned their attention to the research and development of static charging and dynamic charging of electric vehicles.

In 2015, EV WPT's TRL curve reached TRL6 in the private sector due to the early maturing of the theoretical framework. After 2019, the development of EV WPT in the private sector became more mature, and the curve reached TRL7 in 2020, indicating some technical challenges.

Now, the challenges are basically solved, but the costs are still high. At present, the time to market is not mature enough, but products in the private application field are expected to be launched in the next one to two years; with small-scale production of EV WPT products the curve expected to reach the TRL8 level in 2021-2022. It is expected that with the large-scale production of EV WPT products for private applications, the curve will reach the TRL9 level by 2025.

In the public application field, it also refers to the application achievements of WPT in mobile phone wireless charging technology and the theoretical knowledge of extended applications. The TRL curve reached TRL3 in 2010, rising year by year. By 2019, the curve had reached TRL6, but due to the establishment of relevant standards and technical limitations, even though the Chinese scientific research team has produced complete product samples and conducted several real-life tests, the relevant test parameters are still not ideal.

The following areas are perceived to be challenging:

Charging efficiency, electromagnetic radiation levels, and other indicators are expected to improve further, but currently fail to meet the standards for passing experimental tests for public domain applications.

It is expected that the related technology and test parameters will improve after the relevant national standards of EV WPT in the public application field are released in the next two to five years, when the curve may reach TRL7 in public applications. However, it is estimated that it may take about 6-10 years to reach TRL8 in the public domain.

PART FIVE - ANALYSIS

Forecasted development strategy

Figures 6 and **7** below illustrate the development of wireless charging technology in China in the private and public domains, both of which have different contexts, prerequisites and demands. Therefore, each domain needs specific system solutions before full scale use can be put into practice.

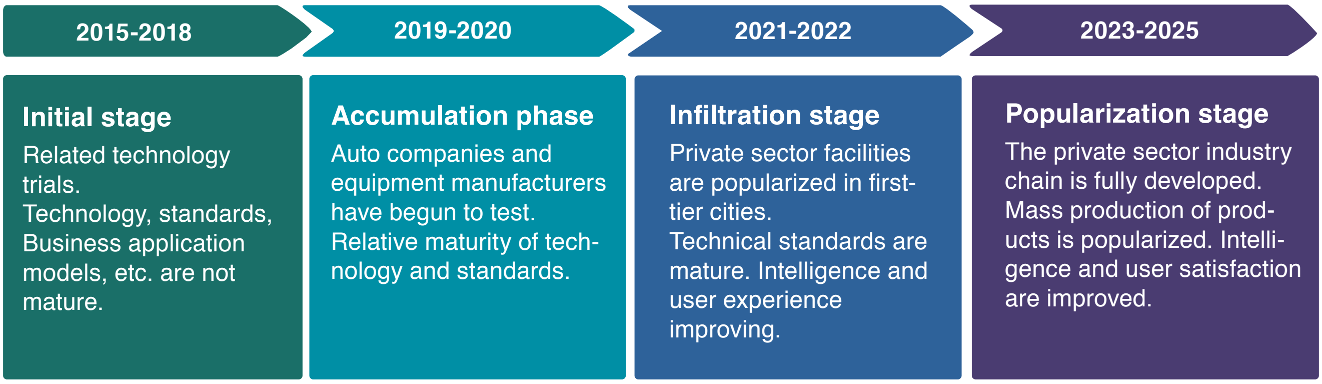


Figure 6: China's EV WPT private field development strategy forecast. Edited and drawn by Shengdong Zu
Source: Based on the above comprehensive analysis

As seen in **Figure 6**, the main development trends in the private domain are:

- The wireless charging technology of electric vehicles in the private application field has achieved a certain degree of development. Against a background of accelerated development of the electric vehicle industry in recent years, new development breakthroughs will be made, and WPT may become mainstream method of electric vehicle charging in the future.
- The wireless charging system for electric vehicles in private applications is currently not a mainstream charging method, and most of them are still based on conductive cable-based charging piles. The key to WPT development is whether it can achieve better charging usage and performance than charging piles.
- The WPT business model is also one of the key factors in popularizing the development of wireless charging systems in private applications.

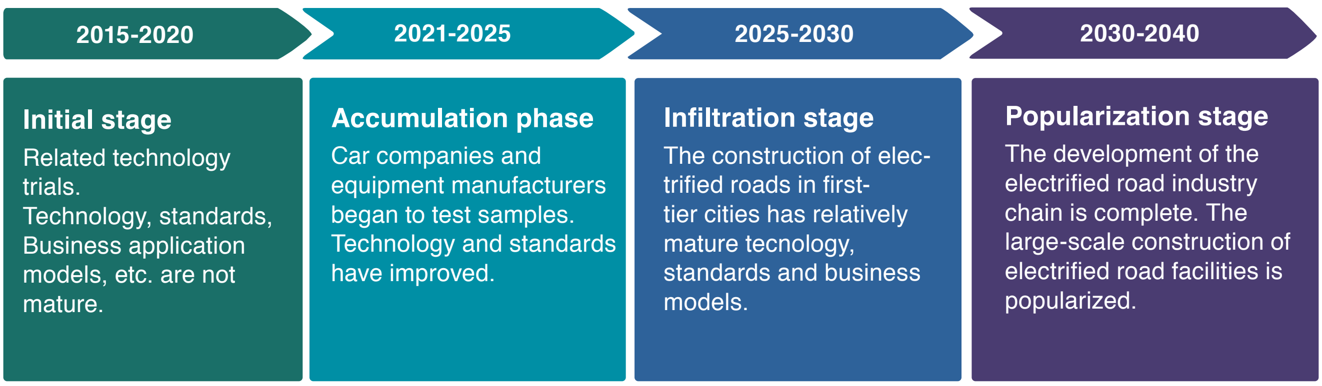


Figure 7: China's EV WPT public field development strategy forecast. Edited and drawn by Shengdong Zu
Source: Based on the above comprehensive analysis

As seen in **Figure 7**, the main development trends in the public domain are:

- At present, the public application of wireless charging for electric vehicles in China is still in the experimental stage, and there may not be significant development in the short term.
- As the Chinese government vigorously develops electric vehicle charging and swapping facilities, the charging method of electric vehicle wireless charging systems in the public domain may be affected to a certain extent. Although this has not the mainstream development direction in recent years, as China's electric vehicle ownership reaches a certain proportion, wireless charging systems for electric vehicles in the public domain is bound to become one of the important charging methods in the future.
- At present, the main problem that electric vehicle wireless charging has faced in the public domain is the formulation of standards and breakthroughs in related technologies. As these technical challenges are solved further, the business model will follow, and be applied to this market.

Figures 6 and **7** shows the differences in the development speed of wireless technology for private and public domains. The requirements are different, and the solutions needed to be developed are also different. The most important difference is the standardization development and full-scale development implementation. In both domains the eco-systems are different and it thus more complex to implement wireless technology in real life.

Challenges

In 2020, there were about 360 million vehicles in China, of which 270 million were passenger vehicles, accounting for 75% of the total number of motor vehicles; the new energy vehicle population was 4.17 million, a year-on-year increase of 9.45%.

According to the forecast of the State Grid Electric Vehicle Company, the number of electric vehicles in China will reach 300 million in 2040.

China is a huge potential market for electric vehicles, but it also faces many challenges. To realize the electrification of transport, several measures need to be taken:

- Ensure that the renewable energy production meets the electricity required to fuel the growing electric vehicle fleets of passenger vehicles, trucks, and buses. It is complex to expand the volume of electric vehicles and at the same time ensure fully electrified transport if those vehicles are not charged with renewable energy.
- Ensure that the charging infrastructure is developed and installed at a level that can match and support the growing number of electric vehicles.
- Ensure that the charging infrastructure is built of several complementary technical systems that can support the electrification of large and densely populated Chinese cities, with limited space for individual solutions i.e. charging piles for all vehicles.

One specific challenge is to realize the research and development and the application of EV WPT in the private and the public domains as intended in 2021-2026, and to meet the identified challenges:

- To finalize the formulation of relevant standards that, by 2020, were not complete and comprehensive.
- To ensure that international standards complement Chinese national standards to facilitate global functioning of wireless charging
- To ensure that the technical level of wireless charging technology meets consumer expectations and requirements to be useful in public domains
- To ensure that the required business model is developed that to match the huge initial investments in the infrastructure for wireless charging technology.

The above points are the main challenges that we can identify in the development of Chinese wireless charging technology today.

Being the leading country in the development of electric vehicles, and being the largest market for electric vehicles, it is important to solve these challenges.

PART SIX - CONCLUSION

As we have seen in our research, China started the technology development of wireless charging technology as early as 20 years ago. However, the technical challenges have shown to be more complex than expected, and the development time has been extensive. However, the most problematic challenge that we have seen is related to the lack of global standards to achieve interoperability and safety in terms of radiation while charging.

To build fully functional wireless charging systems is complicated, as stand-alone systems and almost impossible to mount on vehicles after the vehicle is sold. The wireless charging systems are dependent on OEMs' capabilities to use the technology, commercialize it in their own product development and build it into their own product architecture. For this reason, it's crucial to achieve interoperability across brands and models.

Only when there is interoperability based on general global standards can third party wireless charging station providers install and operate the large-scale wireless charging stations, parking places, garage charging etc., or dynamic wireless charging along public roads and streets.

Looking at the capability of wireless charging technology in 2020, its usability is mostly in static stationary charging situations. the implementation of dynamic wireless charging will take more time; the impact on road infrastructure needs to be explored, and the interoperability issues need to be solved.

According to TRL development level analysis, EV WPT in the private application field has reached TRL7, and is expected to reach TRL8 in one to two years. In the EV WPT public application field, the technical level has reached TRL6. Although complete product samples have been produced in China, and several tests have been carried out in real-life use, due to technical limitations and the establishment of relevant standards, test parameters are not yet ideal. It is expected that the required test parameters will be improved after the implementation of the relevant national standards.

The development speed of commercializing the wireless charging technology is still uncertain. The key is whether the challenges faced by EV WPT can be solved smoothly. With the construction and improvement of the technical standards system, the improvement of the technology, the system design and construction, the training of talented human resources, and the interaction with government's guiding role, are some major issues that must be successfully overcome. Then, China's EV WPT technology is expected to enter a new stage of rapid development.

The Chinese government has given strong support to the development policy of electric vehicles. Chinese university teams, automobile companies and equipment manufacturers have continuously made new breakthroughs in the research of EV WPT technology. From the current point of view, many car companies have developed corresponding products in the private application field of EV WPT and are ready to put them on the market. Equipment manufacturers are also constantly developing more reliable products that are commercially ready. However, no usable products have yet been put on the market in the public application field due to lack of standards.

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