# Penetration of Electric Vehicles into the Greater Bay Area

**Yang Andrew Wu and Songdan Nancy Guo**

**Abstract** Green technology has increasingly penetrated our daily lives over the past decade. Electric vehicles (EVs) have been widely accepted by both corporate users and individual customers. Recently, the Chinese government has been firmly driving forward its macro-economic policy, "Made in China 2025," in manufacturing and industry. At the same time, Chinese citizens are demanding a cleaner, healthier natural environment for their urban lives. Promotion of EV has turned out to be one attractive solution for a large number of stakeholders from various sectors. This chapter begins with a review of cutting-edge EV technology development internationally. It covers smart control and driving technology, new batteries, and energy storage devices. It is followed by a comparative analysis of a range of policy incentives currently effective in the Greater Bay Area (GBA) of China. These policies from different authorities and departments need subtle cooperation in order to be fully executed. This chapter discusses multiple incentives from three aspects: technology, economics, and policy direction. The author believes that both EV manufactory and consumption in the GBA will experience steady growth in the coming years. We conclude that an upward trend of EV penetration in the GBA will positively contribute toward energy sustainability as well as the green finance of projects in the future.

**Keywords** Electric vehicle · Sustainable development · Energy policy · The Greater Bay Area · Green finance

## 1 Current Status Quo of EV Technology Development

Electric vehicles are not exactly new things. It has been more than a century since the first small-scale electric vehicle was invented. However, in the 1920s, with the discovery of enormous quantities of crude oil all over the world, gasoline prices quickly fell to affordable levels, and the construction of infrastructure such as roads and gas stations improved, making fuel vehicles more cost-effective. Since then,

Y. A. Wu (✉) · S. N. Guo
School of Professional Education & Executive Development, College of Professional & Continuing Education, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China
e-mail: andrew.wu@cpce-polyu.edu.hk



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no major breakthroughs have been made in battery and cruising technologies [1]. Consequently, electric vehicles have gradually lost their comparative advantages and have been overtaken by fuel vehicles with internal combustion engines.

After entering the second half of the twentieth century, and after two large market shocks in the oil industry, the auto market and the public began to focus on new energy vehicles. This change has been led by electric vehicles. As a result of poorer air quality since the 1990s, more and more people have examined the possibility of introducing commercial electric vehicles into our transportation system [2]. New products with lower emissions, greater efficiency, and even zero emissions have been under research and development. Under the influence of a variety of factors such as the continuous rise of global oil prices and the increasingly strong demand for environmental protection in the 2010s, the commercialization of electric vehicles has once again been put on the agenda by governments and major automobile companies.

One major difference between a fuel car with an internal combustion engine and an electric vehicle is the powertrain system. The fuel car's own powertrain system consists of the engine assembly, the gearbox assembly, and the fuel tank. The powertrain system of the electric vehicle is powered by the battery pack. The motor and the electric control system are designed so that the power battery pack replaces the fuel tank, the drive motor replaces the engine, and the electric control system replaces the gearbox [3]. There are now a large number of manufacturers of these electric vehicles worldwide. In this paper, we have selected three typical examples from China, Japan, and USA for a brief overview.

In China, BYD started business in the battery market and has a solid background in lithium iron phosphate battery technology. In 2008, BYD launched the F3DM with a lithium iron phosphate battery. The F3DM was the world's first plug-in hybrid vehicle with a top speed of 150 km/h [4]. The 100-km cruising range was also achieved in pure electric mode, and it set a world record at that time.

At the end of 2010, after nearly ten years of research and development, Nissan launched its pure electric vehicle, the Leaf, equipped with a lithium manganese battery. The first-generation Leaf had a cruising range of 160 km. Its lithium manganese battery with a capacity of 24 KWh was provided by NEC and Nissan's joint venture—AESC. The energy density reaches 140 wh/kg [5].

In the USA, Tesla launched the iconic electric racing car Roadster in 2008, and the Model S, a luxury sedan equipped with a ternary battery (nickel–cobalt–aluminum/NCA), in 2012. The Model S can reach a top speed of nearly 200 km/h. Its ternary battery is supplied by Panasonic and has an energy density of 170 Wh./kg, with a battery capacity of 85 KWh [6]. It can achieve a cruising range of nearly 500 km.

The key factor for the realization of innovative electric vehicles is the development of battery technology. It is predicted that the large-scale commercialization of all-solid-state batteries might not be realized until 2025–2030, or even later. In addition, we can be fairly sure that technological changes in high-efficiency drive systems will occur in the next five years, that is, the motor drive system will become faster, more efficient, and achieve greater miniaturization.

The history of technological progress of electric vehicles is also a history of power batteries products. By comparing the representative models of those three electric vehicles, we can see that the development and application of new battery materials, energy density, and cruising range have been improving over time throughout the industry.

The battery mainly includes five performance indicators: energy density, safety performance, cycle performance, high and low temperature performance, and cost. Among the current mainstream cathode materials, lithium iron phosphate has the best safety performance, cycle performance, and lowest cost, but has a poor low temperature performance and low energy density; lithium manganese is relatively safe in terms of safety performance, cycle performance, and cost [7]. However, poor high temperature performance and low energy density are drawbacks; ternary materials are relatively poor in safety and high in cost, but energy density is higher than the other two materials. Due to the passenger car's requirements for cruising range, the current ternary materials, especially the high-nickel ternary, are increasingly favored by the industry, and the market share continues to increase.

## 2 Overview of EV Promotion Policies in the UK and USA

As early as the 2000s, developed countries such as the USA and those in Europe had begun to vigorously promote the development of new energy vehicles and had launched a series of policy incentives to promote the construction, sales, and use of new energy vehicles. In fact, the concept of new energy vehicles was first proposed decades ago.

In 2009, the UK introduced the ULEV Strategy to promote the nationwide use of ultra-low emissions vehicles, especially new energy vehicles. The details of this program were completed in 2013 [8]. The significance of the plan was to lay a solid foundation for the infrastructure construction of new energy vehicles. As we know, the promotion of new energy vehicles is often subject to the progress of basic design and construction such as charging equipment. The ultra-low emission vehicle program provides policy guidance for infrastructure construction across the UK, including charging stations and peripheral support settings. In London, for example, it is expected that more than 6,000 charging piles will be completed by the end of 2019.

Further to this, the British government proposed in the air quality plan promulgated in July 2017 that it would completely end the primary market sales of traditional fuel vehicles by 2040 [9]. In October of the same year, the Ministry of Commerce and the Ministry of Energy promulgated the Clean Growth Plan [10], promising that the government will spend around a billion pounds to promote the market share and actual utilization rate of new energy vehicles. Furthermore, the British government's Climate Change Committee proposed in January 2018 that the UK completes the goal of ensuring at least 60% of new cars on the road in 2030 are ULEVs. The development of the new energy automobile industry in the UK has received unprecedented political and economic support.

In the USA, various state governments have also introduced different policy support and economic incentives, including estimates of infrastructure facilities, tax incentives, and subsidy incentives. These tend to be most prominent in coastal cities along the West Coast. According to the International Clean Energy Transportation Committee research report [11], as of the end of 2017, more than 200 cities and regions in the USA had begun to popularize new energy vehicles, including hybrid vehicles. This policy support and the economic incentives that go with it are even greater than in the UK.

More importantly, European scholars have proposed a policy system for the establishment of comprehensive new energy vehicles and related infrastructure networks. British scholar Benjamin K. Sovacool [12] pointed out that a combination of automotive technology networks and social science research, from the perspectives of technology, culture, and society, was necessary in order to accelerate the process of consumer acceptance of new energy vehicles. Swedish scholar Zeinab Rezvani and his colleagues have tried to find out why new energy vehicles have not been widely covered so far in terms of consumer behavior habits [13], consumer rational analysis, environmental attitudes, and living habits. It seems likely that consumer acceptance of new energy vehicles is a gradual and long-term process. The quarterly research report of the internationally renowned consulting firm McKinsey [14] pointed out that the penetration rate of new energy vehicles in international metropolises is gradually increasing, and that future market prospects are becoming more extensive.

## 3 EV Promotion Policy in the GBA of China

The industrial policy changes of China's new energy vehicles can be roughly divided into three stages, namely the government's macro-strategic planning (2001–2006), the establishment of industry access rules and comprehensive subsidies (2007–2015), and the post-subsidy stage (2016–the present).

In the first phase, the technical route of new energy vehicles has not been fully determined. The focus for a large number of countries in the world is on hydrogen fuel cells, and China is no exception. At this time, there are not many government policies. Most of the policies are macro-strategic guiding policies, focusing on the planning and development goals of new energy vehicles. For example, in 2001, China launched the "863 program of electric vehicles" and planned to build the three vertical and three horizontal new energy vehicle's development layouts [15]. In 2004, the National Development and Reform Commission issued the "Automobile Industry Development Policy," which highlighted the development of environmentally friendly technologies and electric vehicle technologies for sustainable development [16]. In 2005, the central government introduced measures to optimize the structure of the automobile industry, promote the development of clean vehicles and electric vehicles, and outline the development goals of electric vehicles over the next 25 years [17].

In the second phase, China's new energy vehicles have made major breakthroughs in key technologies. Since 2007, China's independent research and development of pure electric, plug-in hybrid and fuel cells of new energy vehicle products has progressed. At the 2008 Beijing Olympic Games, the Ministry of Science and Technology organized relevant domestic automakers to provide a concentrated display and use of about 500 new energy vehicles for various types of energy-saving at the Olympic Games. This opened the first year of new energy vehicles in China. At this stage, the government's policies began to be refined, the industry's access conditions and corresponding norms and standards were established, and a series of financial subsidy policies were gradually introduced, laying a solid foundation for the industry to follow.

Since November 2007, the "New Energy Vehicle Production Access and Management Rules" have officially begun to be implemented in China. These rules make specific provisions for the definition of new energy vehicles, the qualifications of new energy vehicles, the conditions for production access, and the requirements for reporting. In 2009, the government issued the first subsidy policy for energy-saving and new energy vehicles, thereby subsidizing these vehicles in the public service sector. In 2010, the government subsidized the private purchase of new energy vehicles and subsidized them at the rate of 3,000 yuan per KWh. The maximum subsidy for plug-in hybrids was 50,000 RMB per EV car, and the maximum subsidy for pure electric vehicles was 60,000 RMB per car [18].

After the Chinese government began to subsidize new energy vehicles in 2009 and 2010, the domestic electric vehicle market began a more vigorous development. In 2011, domestic EV sales were only 8000 units, while sales growth in 2016 had reached 336,000 units. This accounted for nearly 45% of the global share, surpassing the USA to become the world's largest electric vehicle market [19]. 2014 is considered to be the breakout year for domestic electric vehicles. In 2015, it ushered in a full-scale upsurge in the industry. The main reason was that the development of new energy vehicles in China was lower than expected in 2010-2013, in order to complete the "Energy Conservation and New Energy Vehicle Industry Development Plan 2012." The target for the production and sales of pure electric vehicles and plug-in hybrid vehicles (including passenger cars and special vehicles) is 500,000 units by year 2020. The government introduced a number of policies in 2014 to further support the development of the industry. As a result, the industry has experienced explosive growth. The decline in subsidies has been delayed, and the list of cities to be promoted has increased, following the example of the Greater Bay Area.

In November 2016, the State Council issued the "13th Five-Year Plan" strategic emerging industry development plan. The plan has proposed that by 2020, the annual production and sales of new energy vehicles will exceed 2 million, and the cumulative production and sales will exceed 5 million. The overall technical level will keep pace with that internationally. Finally, a group of internationally competitive new energy vehicle producers and key components enterprises will be formed.

In the third phase, the state made a series of adjustments to the subsidy policy, including investigating the fraudulent behavior of some car companies, differentially adjusting the subsidy range of passenger cars and special vehicles, and introducing a long-term mechanism such as "double points" to guide transformation and upgrading of car companies.

From the results of domestic EV sales, we could observe that sales of pure electric vehicle increased from 5600 in 2011 to 257,000 in 2016, nearly 50-fold in five years. The sales of plug-in hybrid vehicles increased from 2600 in 2011 to 79,000 vehicles in 2016, an increase of around 30-fold. In general, BEV has achieved a faster growth rate than PHEV, and the proportion of BEV's total sales has remained at around 70% [20].

Regarding the passenger car, in addition to the subsidy range of the post-subsidy era, the policy has adjusted the subsidy amount for different cruising ranges. In 2016, the subsidy value of the high cruising range was greater than that in 2015. The subsidy policy aims to encourage further development of high cruising ranges and high energy density.

After the accumulation of the past three five-year plans, China's new energy vehicle industry has grown from scratch and has made significant progress in key components, e.g., vehicle integration technology, technical standards, testing technology, and demonstration operations. Powertrain control, drive motor, and power battery are the three key components for strategic research and development.

At present, the policies and regulations on new energy vehicles in mainland China are mainly issued jointly by the National Development and Reform Commission, the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the Energy Bureau. The policy and planning statistics that have major direct impacts on the development of new energy vehicles in the Greater Bay Area of Guangdong, Hong Kong and Macau are shown in Table 1. The table also contains comparative analysis of the key parts of each policy. The analysis focuses on the actual impact and application of the Greater Bay Area in Guangdong, Hong Kong, and Macau.

The governing bodies of the Greater Bay Area have always attached great importance to the construction of an ecological civilization and the scientific path to a low-carbon and sustainable development. "It is necessary to have Jinshan Yinshan and green water and green mountains." In fact, Guangdong Province, especially the Greater Bay Area has been at the forefront of the development of new energy vehicles. A number of important scientific and technological breakthroughs began life here.

## 4 The Increasing Trend of EV Penetration in the GBA

The Provincial Development and Reform Commission of Guangdong Province has pointed out that Guangdong will fully implement the national development strategy for the promotion and application of new energy vehicles (GDRC 2010). It is effectively alleviating energy and environmental pressures, and the relevant departments

**Table 1** Brief summary of key policies for EV promotion in 2017 and 2018

| Category | Policy | Authorities | Summary |
|---|---|---|---|
| Guideline | "Medium and Long-term Development Plan for Automobile Industry" [24] | Ministry of Industry and Information Technology (MIIT), Development and Reform Commission (DRC), Ministry of Science and Technology (MST) | By 2020, to build several domestic automobile companies into the world's leading new energy auto companies, and to increase their global market share.<br>By 2025, to build a top-tier smart network for new energy vehicles |
| | "National Guideline for Vehicle Network Construction and Industrial Standard System" [23] | MIIT | Actively build a new generation of intelligent networked vehicle standard systems, to support functions such as assisted driving and automatic driving; independent research and development of safety standards, and communication standards |
| Tax | "PR China Vehicle Purchase Tax Law" [27] | Ministry of Finance (MoF), Taxation Bureau (TxB) | For eligible new energy vehicles, the vehicle purchase tax will be exempted or reduced. |
| Subsidy | "Notice on Liquidation of New Energy Vehicle Subsidy Funds in 2016" [21] | MoF, MIT, DRC | New energy vehicles purchased by non-individual users may also apply for subsidies, which require a cumulative travel of over 30,000 km. Subsidy standards and technical requirements are implemented on an annual basis in accordance with the driving permit |
| Facilities | "Guidance on Promoting Energy Storage Technology and Industrial Development" [26] | MoF, Energy Bureau (EnB), MIIT, DRC, MST | Multi-angle to promote the construction and development of supporting infrastructure for smart charging, power batteries, and communication base stations of new energy vehicles. Improve battery life cycle management, give power battery gradient use, and improve energy efficiency |
| Standards | "Promote the development plan of the automotive power battery industry" [22] | MoF, MIIT, DRC, MST | Improve the quality of new energy vehicle batteries, research and promote the application of a new generation of lithium-ion automotive power batteries; develop and test new battery systems with chemical principles |

(continued)

**Table 1** (continued)

| Category | Policy | Authorities | Summary |
|---|---|---|---|
| | "New energy vehicle manufacturing enterprises and product access management regulations" [25] | MIIT | Increased access thresholds for new energy vehicles in research and development, design, production, sales, after-sales, safety, etc., and strengthened regulatory requirements |

of the province and relevant enterprises are closely cooperating to actively promote the development of the new energy automobile industry. Supporting facilities for electric vehicles have also been vigorously developed, and the overall construction is in good condition.

According to China Electric Vehicle Charging Infrastructure Promotion Alliance statistics, as of the end of 2017, the number of new energy vehicles in the country exceeded 1.7 million, and Guangdong Province had produced more than 200,000 new energy vehicles, accounting for about one-eighth of the country. There are now 214,000 public charging piles in the country. There are about 690 charging stations in the province, 38 intercity charging stations, and more than 60,000 public charging piles. The total number of charging piles is over 80,000, and the ratio of pile to truck is as high as 1:2.4, far exceeding the national average. New energy vehicles are mainly concentrated in the Pearl River Delta region. As a consequence, the charging facilities in the Pearl River Delta are being rapidly developed, accounting for more than 90% of the province's charging facilities [28]. This basically meets the needs of charging and replenishing electric vehicles in Guangdong Province.

According to the statistics of the Hong Kong Trade Development Council, the GBA has a land area of about 55,904 $km^2$ and a population of nearly 70 million [29]. The regional GDP is about 1513.4 billion US dollars, and the per capita GDP is more than 20,000 US dollars. If we compare it with the New York metropolitan area and the Tokyo bay area of Japan, we see that the land area, population share, total GDP, and even per capita GDP of GBA are higher than the New York metropolitan area and the Tokyo bay area. The economic development and future potential of GBA is tremendously encouraging.

*Trend 1: Public vehicle first*

Zhuhai government has established a pioneer project at one bus charging station on Haihong road. The bus charging station was put into operation in October 2016. According to data obtained, in 2017 the electric vehicle charging capacity of Zhuhai Power Supply Bureau accounted for 70.3% of the electric vehicle charging capacity within the Guangdong power grid, of which electric bus charging accounted for the majority [30].

At present, all parts of Guangdong are accelerating the promotion of electric buses. "Implementation Opinions of the General Office of the People's Government of Guangdong Province on Accelerating the Promotion and Application of New Energy Vehicles" has pointed out that the proportion of renovated or newly added pure electric buses in the Pearl River Delta region shall not be less than 90% by 2020. It is required to effectively realize the large-scale and commercial operation of pure electric buses.

In addition to buses, Shenzhen is also targeting other vehicles such as taxis. The charging frequency of private cars is not high. The main application scenarios such as communities and units are still small. However, electric taxis can drive the cultivation of the public charging market more than private electric cars. Currently, Shenzhen has promoted 16,359 new energy buses, which are 100% purely electrified, except for emergency transportation capacity. The number of pure electric taxis now exceeds 13,000, and the pure electrification rate is 65%. A total of about 40,000 charging piles have been built [31].

*Trend 2: Striving for innovations*

Guangdong government has published the "Electric Vehicle Charging Infrastructure Planning (2016–2020)" which states that by 2020, Guangdong Province will build 1490 centralized charging stations and build about 350,000 decentralized charging piles, totaling about 410,000 in the province. A large-scale charging network for electric vehicles will be realized, and the electric vehicle will be able to travel smoothly through the Pearl River Delta.

Shenzhen has built China's first pilot project of "Smart Parking + Charging Integration" roadside charging piles. This "parking + charging" mode not only solves the car owner's cruising range anxiety, but also helps to balance the grid load and avoid the impact of large-scale centralized charging on the power grid.

The Shenzhen government has transformed one power substation at Lianhua Mountain into a multi-functional green "change + charge" power station, which covers an area of more than 3000 square meters. In addition to the original substation, the roof has also been transformed into a photovoltaic power generator. This can satisfy the fast-charging demand of 720 electric vehicles in one day.

Despite the development of charging facilities in recent years, the land issue is still the most difficult issue restricting the development of charging facilities. In particular, the legal use of land is still facing significant problems, and illegal construction is not uncommon. For example, in terms of bus charging facilities, there is no independent planning land for bus charging stations, most of which are built on non-state-owned temporary land. The huge gap in bus stations directly restricts the construction of new energy bus charging facilities. This makes it difficult for charging stations to meet daily charging and maintenance needs.

In terms of social charging facilities, the existing building parking lots and public parking spaces are limited, and there is a contradiction between the construction of charging facilities and the use of existing parking spaces. The operating income of charging facilities is problematic to achieve, which makes it difficult to fully cover the construction of charging facilities in the short term.

*Trend 3: A long road ahead*

New energy vehicles have not yet been widely accepted by individual consumers. An effective commercial charging facilities' operation is still being developed. The utilization rates and return rates of most public charging facilities are low, which affects the enthusiasm of operators for investing in the required infrastructure.

In order to standardize the planning, construction, and operational management of charging facilities and to promote the use of electric vehicles, the province has formulated detailed measurements in accordance with the principles of "appropriate advancement, reasonable layout and regional differences." Guangdong Province Expressway Charging Infrastructure Planning and Construction Plan (2018–2020) requires that by 2020, the province's trunk highways (all highways except the city ring road and expressway) will be "fully charged." New expressway service areas should be equipped with fast-charging piles, and reserved charging facilities' interfaces should be present at a ratio of not less than 50% of the total number of parking spaces. Relevant standards are included in highway design and acceptance specifications.

In 2017, Guangdong Power Grid established the Guangdong Electric Vehicle Charging Infrastructure Promotion Alliance to expand more than 50 influential enterprises in the industry, promote industry standardization, and build a provincial-level electric vehicle charging service via an "easy-to-charge" app on mobile phones.

The Provincial Development and Reform Commission has also made it clear that the role of the provincial charging facility alliance should be fully utilized. Expanding the influence of the charging facility alliance, and building a public information intelligence service platform, should further realize interconnection and interaction, and improve the level of charging services.

It has been found that the proportion of plug-in hybrid vehicles in the entire new energy vehicle market is increasing. In fact, compared with pure electric vehicles, plug-in hybrid vehicles can better balance mileage anxiety with the cost of pure electric vehicles and can improve the efficiency of traditional internal combustion engines. The energy efficiency of the entire vehicle is improved, and the battery usage reduced. This further reduces the vehicle weight and vehicle costs.

In the GBA, each city has its own strengths. The economic advantages have complemented each other and created huge business opportunities. For example, Guangzhou, Foshan, and Dongguan have always been important manufacturing bases, while Shenzhen has had the advantages of high-end manufacturing, innovative technology, and information technology industries; Hong Kong is world-renowned for global finance, international shipping, and offshore asset management; Macau is a popular tourism and leisure center. The complementary advantages and common development of each city have created tremendous economic growth momentum in the past decades.

These macro-economic conditions have provided a fertile soil for the rapid development of new energy vehicles in Guangdong, Hong Kong, and Macau. As far as Hong Kong is concerned, the number of new energy vehicles has grown rapidly over the past eight years, from less than 100 vehicles in 2010 to 11,345 vehicles in October 2018 [32]. At present, there are about 83 types of new energy vehicles that have been approved for driving in Hong Kong, including 58 private cars and 25 public and commercial vehicles.

An important reason for the rapid development of new energy vehicles in Guangdong, Hong Kong, and Macau is the provision of convenient and fast-charging devices and extensive infrastructure coverage. In Hong Kong, for example, CLP Holdings Limited and Hong Kong Telecommunications Co., Ltd. jointly established an equity joint venture, Smart Charge (HK) Limited, in August 2016 to actively promote one-stop smart charging services for new energy vehicles in Hong Kong. It covers a number of residential, office, and public facilities throughout the territory. The charging service can be electronically paid through Hong Kong Telecom's mobile wallet for the convenience of the public.

Tax relief is another important reason for the rapid development of new energy vehicles in the Greater Bay Area. Take Hong Kong as an example. In the past few years, the HKSAR government has been implementing a full reduction of the first registration tax on new energy vehicles. This policy provides great encouragement and support for citizens to purchase new energy vehicles. At the same time, the Hong Kong Special Administrative Region government has taken into account the sharp increase in the number of private cars. It decided that this policy would expire on March 31, 2018, and the upper limit would be reduced to HK$97,500. However, taxes on commercial new energy vehicles and motorcycles have been retained. These items will be reduced in March 31, 2021. On the other hand, the HKSAR government has introduced a "one-for-one" scheme, in which eligible existing car owners purchase new energy private cars and destroy their eligible old private cars at the same time. This will result in higher first-entry tax deductions. The highest amount is HK$250,000. This policy is expected to further promote the penetration rate of new energy electric vehicles in Hong Kong.

In addition to financial subsidies, the government has also introduced a series of tax incentives for consumers and car companies, including the purchase of pure electric vehicles, plug-in hybrid cars exempt from vehicle purchase tax, and the sale of new energy vehicles. The VAT rate for parts and components has been adjusted to 13%. In addition to cooperating with the introduction of subsidies, local governments have also used a series of non-financial incentives such as unlimited licenses to encourage consumer to purchase new energy vehicles.

Apart from private cars, new energy public operating vehicles, such as electric buses, can also be seen as one of the future development directions of Guangdong, Hong Kong, and Macau. The HKSAR government started to promote electric buses in 2012. At present, it has subsidized the franchised bus companies to purchase 36 single-decker electric buses and has already carried out trial operation on various routes in Hong Kong. According to the public information of the Guangdong provincial government, as of the end of April 2018, there were 56,000 pure electric operating vehicles in Guangdong Province; and in 2017, new energy vehicles accounted for more than 95% of the new and updated public buses in the province. The Guangdong Provincial Department of Transportation plans to implement complete bus electrification in the Pearl River Delta city by 2020. The booming electric buses have also provided a new engine for economic growth in the GBA.

## 5 A Positive Contribution in Sustainable Energy and Green Finance for the GBA

At the end of 2015, "green finance" was included in China's "13th Five-Year Plan," which clearly outlined the establishment of a green financial system, including the development of green credit, green bonds, and the establishment of a green development fund [33]. In August 2016, the seven ministries and commissions including the People's Bank of China issued the "Guiding Opinions on Building a Green Financial System," marking the official formation of China's national strategy for building a green financial policy framework. In June 2017, the State Council executive meeting decided to select places in Zhejiang, Jiangxi, Guangdong, Guizhou, and Xinjiang to develop a green financial reform and innovation pilot zone. The aim is being to conduct pilot exploration for the full implementation of China's green finance. The development of the green financial system officially entered the stage of implementation.

In August 2017, the central government approved the "Guiding Opinions on Building a Green Financial System," pointing out that the development of green finance is an important measure to achieve green development and an important part of supply-side structural reform. At the same time, they encouraged use of green credit, green bonds, green stock indices and related products, green development funds, green insurance, carbon finance, and other financial instruments and related policies to serve green development.

China actively promotes the issuance of green bonds in the international market and has caused the global green bond market to flourish. In 2016, the issuance of green-labeled bonds in the Chinese bond market exceeded 200 billion yuan. Accounting for nearly 40% of the global circulation, it has become the world's largest green bond market.

In the GBA, the macro-economic foundations of green finance have been well established. The GBA has consistently maintained a stable inflation rate in the past few years, much better than other regions of China. The education level of the population is generally high, and the unemployment rate has been at a low level for several consecutive years. In addition, its economic development has grown steadily, especially in innovative industries and services named as "new economic businesses." It is particularly noteworthy that the financial situation of many cities in the GBA is good enough to support the overall future development of the economy and can provide precious opportunities in the region.

In the past a few years, the GBA has successively promoted large-scale multi-dimensional cooperation platforms such as the districts of Nansha in Guangzhou, Hengqin in Zhuhai, and Qianhai in Shenzhen. The formation of new economic systems has been accelerating and is represented by innovative service industries. At the same time, the GBA has also effectively promoted the cooperation and development between the GBA and other mainland regions, especially for financial industries, providing convenient conditions for the economic development in both industry and capital markets.

In order to undertake research work in the area of green finance, there are great challenges in terms of data measurability and accountability.

At present, many scholars have emphasized the need to improve three aspects of green financial standards. First, there is a lack of consistency in standards for green bonds from the three rule makers—the Bank of China, the National Development and Reform Commission, and the exchange. Secondly, the standards of various green bonds are not completely consistent with the standards of green credit, resulting in assets identified as green credits not being able to match the green bond standards after securitization. Thirdly, domestic green bond standards are not completely consistent with international standards.

Therefore, we really need a new way to measure the "green value" of each economic activity to measure the degree of "greenness." Only when it can be accounted for and measurable, can it be recognized by the international community. It can then avoid regulatory arbitrage in domestic operations, so that the incentives and restraint measures discussed by all parties can be implemented.

The international research paradigm in dealing with global climate change is worth studying. Since natural science research shows that carbon dioxide is the largest greenhouse gas, carbon emission reduction is the primary goal. All economic activities therefore have a corresponding carbon emission level or carbon neutral level. This is used to measure the environmental impact.

It is difficult to rely only on commercial activities to reveal the variables that can be used to measure the degree of "greenness." Relying on economics or finance research is the correct path, yet requires enormous amount of work. It requires a degree of interdisciplinary integration.

Nowadays, the commercial costs of undertaking green finance business are very high. It is difficult to evaluate green measures. Thus, obtaining "green value" from the output will engender a lot of uncertainties and risks. Those risks may affect public welfare. It is necessary to identify the degree of environmental protection of each enterprise in a relatively transparent environment. This kind of financial reporting system will also provide convenience in disclosing information.

At present, China has become one of the world's largest green debt issuers, and the types of green financial products are quite complex. China's economy is shifting toward greener development, and governments at all levels are very active in institutional innovation for green development [34]. All of these provide a rare historical opportunity for our academic community to conduct original research on green finance.

In June 2017 Guangzhou government established a Green Finance Reform and Innovation Pilot Zone in Huadu District. Over the past year, the Municipal Financial Bureau and Huadu District have closely focused on four major areas, namely the experimental field of green financial reform and innovation; the demonstration zone of coordinated development of green finance and green industry; the new platform for cooperation and development of the GBA; and the assistance of the construction of the "Belt and Road." They aim to firmly grasp the main line of green financial services in terms of real economic development, to vigorously promote the innovation of green financial mechanisms, and to improve the ecological environment of green finance development. Up to now, the green financial zone has helped establish 151 green institutions with a registered capital of 6.9 billion yuan. Several world-class enterprises have set up pioneering projects in the zone, such as CLP and Nissan. They are developing new energy vehicles and intelligent network automobiles, with strong financial resources and support from strategic emerging industries. The green financial zone also actively promotes green travel and enables financial leasing companies to provide green financing services for one hundred electric buses under operation in Huadu district. The green financial zone strives to fully realize bus electrification in Huadu district in the near future and is considering the construction of green buildings during the process of regional development and urban renewal.

The development of green finance has long-term characteristics. As an institutional arrangement, the green financial system mainly supports economic greenification through financial credit, green bonds, green stock indices and related products, green development funds, green insurance, carbon finance, and other financial instruments. Its occurrence, development, and maturity will require a long process of gradual development.

## 6 Future Challenges

In future, the Great Bay Area of China is likely to strengthen its links with the mainland industry and achieve strategic goals in economic cooperation between Hong Kong and Macau and the Mainland. It is expected to maintain steady economic growth and to build a green and healthy sustainable development zone. At the same time, the GBA has a unique geographical location and certain legal advantages. For example, Hong Kong has a key role as an important international shipping center. It is a global economic exchange for "Belts and Roads" Initiatives, and a hub to "go global" for Chinese enterprises. The GBA will take a leading role in the "National Manufacturing 2025" and other national plans as well.

*Challenge 1: Cost of production*

In October 2017, UBS released a report on consumer acceptance of electric vehicles [35]. The report selected consumers from the world's major auto markets as the survey targets, and finally found that most consumers prefer cars with pure electric engines rather than "electric-fuel" dual mode. Concerns focus on high prices, limited cruising range, insufficient number of charging stations, and short battery life. Among these concerns, the high price is the primary reason why most people are not willing to buy electric cars.

A survey conducted by Goldman Sachs in 2016 also found that 50% of consumers believe that the high price is the main factor affecting the purchase of electric vehicles [36], followed by limited cruising range and charging facilities.

Electric vehicles appear as substitutes for fuel vehicles. Similar to the situation when fuel vehicles began to spread rapidly, the rapid decline in cost through technological advancement and efficiency improvement has become the primary factor affecting the popularity of electric vehicles.

Regardless of whether it is an electric car or a fuel car, it is composed of key elements such as a power system, a vehicle body, a chassis, an automotive electronic system, and interior and exterior parts; but the cost ratio of each part is not the same. For pure electric vehicles, the battery and powertrain systems account for up to 50% of the total cost, while for fuel vehicles, the engine and powertrain systems account for only 15% of the total cost. This part of the cost structure difference is the main reason why the current cost of electric vehicles is higher than that of fuel vehicles. How to reduce costs through technological advancement and scale effect is the primary problem that the industry needs to solve.

*Challenge 2: Cruising range*

Under the same external conditions such as vehicle weight and temperature, the cruising range of the electric vehicle is mainly determined by the battery capacity. The larger the battery capacity, the higher the cruising range. Under normal circumstances, the mileage of one-degree electricity is 6–7 km. Therefore, the electric vehicle needs to achieve a higher cruising range. The amount of energy that can be carried (i.e., energy density) can also increase overall battery capacity. The core of the former is the cost issue, and the core of the latter is the technical and material issues.

In those domestically sold pure electric vehicle in 2018s, the cruising range was about 300 km, which can only meet the needs of urban traffic or short-distance travel. A typical fuel vehicle, however, with 40–50 L of fuel tank capacity can usually run more than 500 km.

*Challenges 3: Charging facilities*

Although the number of charging facilities in China has increased, it is still unable to catch up with the rapid growth of electric vehicles on the road. At present, the main factors restricting the construction of charging facilities include long power access period, high cost, difficulty in installing measurement meters, tight urban land supply, and difficulties in site selection. In addition, private construction of charging facilities also faces some other problems, such as construction quality, reporting standards, and auditing issues. The filing process is extremely time-consuming. In terms of charging operation services, there are also technical challenges like interconnection of online payment system, switching between new and old systems, payment safety issues, etc. Currently, it is difficult for private enterprises to make profits through investing in charging stations.

Since some cities have established strict licensing regulation, allowing only new energy vehicles to be licensed free of charge, the drivers of electric vehicles are mainly concentrated in first- and second-tier cities. Those cities are also under vehicle purchase restrictions, such as Beijing and Shanghai. However, for these first-tier cities, there is a widespread shortage of parking spaces. Fixed parking spaces are often the prerequisite for the installation of charging piles in urban residential quarters. These could fulfill the charging needs of more than half of the electric vehicles in Beijing, Shanghai, and other cities. Owners still have to rely on public parking charging facilities.

As for the third- and fourth-tier cities, electric vehicles are currently sold less and are mainly low-speed vehicles. Most of these electric vehicles use lead–acid batteries as the power source. They do not support fast charging, and their electric vehicles generally have independent garages. Therefore, public charging piles or special charging piles built in third- and fourth-tier cities are not considered profitable at the current stage.

The development of the whole industrial chain for new energy vehicles can not only effectively utilize the technological innovation advantages of the GBA, but can also promote the employment and cultivation of high-tech talents. Infrastructure and transportation facilities are among the most important types of investment in economic exchanges and cooperation between countries and regions along the "Belts and Roads" Initiative. New energy vehicles could meet the requirements of such investment cooperation. At the same time, "Made in China 2025" also puts higher requirements on the production design capabilities of new energy vehicles. The innovative design and production capacity of new energy vehicles in the GBA has been greatly improved. Great progress in important areas such as new energy vehicle charging and discharging technology, battery safety management models, and a combination of electric vehicle and power grid technology need to be achieved in future.

The GBA will continuously attract high-tech talent to create scientific and technological values and realize the combination of production, education, and research.

From a technical point of view, another reason why new energy vehicles can be generally accepted by Hong Kong and Macau is that the land area of Hong Kong and Macau is not large, and the cruising range of new energy vehicles is sufficient to meet the daily needs of users in Hong Kong and Macau. With the development of innovative battery technology for new energy vehicles, the cruising range continues to increase. In addition, the charging facilities and related infrastructure in the GBA are well prepared. However, the standardization of charging devices and related infrastructures needs to be unified as much as possible in the future, in order to provide an important basis for the further popularization of new energy vehicles in Guangdong, Hong Kong, and Macau.

Finally, the GBA has a solid market economy and financial industry foundation. Future policy-makers may consider setting up an innovation development fund to encourage innovative high-tech industry research works. Such funds may be jointly established and managed by the government, new energy companies, and financial institutions. The government could encourage high-tech industry to innovate in science and technology, to combine production, education, and research by injecting seed funds. All those suggestions are closely related to talent and intelligence exchanges. The GBA could also consider strengthening exchanges between the various places, encouraging Hong Kong and Macau to invest in Guangdong, and encourage high-tech people from the Mainland to study and do exchanges in Hong Kong and Macau. Mutual investment would therefore be established. By exploring the development space of start-ups and small-to-micro enterprises, youth entrepreneurship and employment rate in the GBA would be largely promoted.

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