



The development of new energy vehicles on economic and environmental benefit: evidence from carbon neutral in Beijing, China

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Abstract. Based on the global warming-induced crisis of fossil energy consumption and the thriving market for new energy vehicles in recent years, this study takes Beijing, China as a case study to examine the current state of the new energy vehicle industry, its development trends, and user feedback. Ultimately, it reveals the upward trajectory of new energy vehicles under China's carbon neutrality goal and highlights their economic and environmental benefits that can be realized by 2050. Drawing from industry surveys and questionnaire results, this paper summarizes the challenges faced by China's new energy vehicle industry and proposes relevant policy recommendations pertaining to technological advancements, industrial growth, and societal engagement. These suggestions aim to provide valuable insights for promoting the development of the new energy industry.

Keywords: new energy vehicles, economic and environmental benefits, carbon neutrality, industrial development.

1 Introduction

Since the implementation of open-door policies and reforms, China's economy has experienced a significant leap in growth, leading to a substantial surge in energy consumption. According to statistics, by 2013, China's total energy consumption had reached 109.9 billion Canadian dollars, with crude oil consumption reaching 20.18 billion GJ [1]. Concurrently, China's automotive industry has undergone rapid development during this period, witnessing an almost hundredfold increase in the number of vehicles compared to 1980. Both car production and sales have achieved global firsts, making transportation one of the largest energy-consuming sectors in China [2]. Due to the rapid rise in vehicle ownership rates, extensive emissions from automobiles have resulted in severe air pollution and carbon emissions that exacerbate global greenhouse effects [3-4]. Furthermore, studies indicate that Earth's fossil fuel reserves are estimated to last only for another 30-40 years before reaching their usage limit around 2050 [5]. However, the emergence of new energy vehicles has significantly improved this situation. The advent of alternative-energy-powered forms of transpor-

tation and subsequent development of charging infrastructure for these vehicles have become effective methods for extending available petroleum reserves. Since plug-in hybrid electric vehicles were introduced into the US market in 2010, the new energy vehicle industry witnessed a remarkable market peak within just one year as sales exponentially increased. This phenomenon greatly impacts economic and environmental benefits towards achieving sustainable road transport systems in the future[6].

Based on the current circumstances, this study utilizes Beijing, China as a case study to investigate and comprehend the new energy vehicle industry, industrial development trends, and user preferences within the city. Through an analysis of policies, market conditions, and user feedback, we aim to predict and analyze future ownership patterns of new energy vehicles. Additionally, considering China's objective of achieving carbon neutrality by 2060, we provide a comprehensive discussion and analysis regarding the economic and environmental benefits that can be derived from the development of the new energy vehicle industry. Finally, based on our research findings, we propose pertinent policy recommendations to contribute to relevant research in this field.

2 New energy vehicle industry research review

2.1 Overview of the new energy vehicle industry in China

In recent years, China's new energy automobile industry is in a stage of rapid development, and major automobile companies have begun to develop and sell new energy vehicles. According to Table 1, BYD Group has become one of the leading enterprises in domestic new energy vehicles with its advantages across the three major fields of automobile, IT and new energy. In 2022, BYD's electric vehicles sold in the price range of about 100,000 to 350,000, covering more consumer grades, models covering cars, SUVs and MPVS, can meet the needs of most consumers for private cars. Other brands such as Peugeot, Mercedes and BMW have also launched electric vehicles, hoping to gain a foothold in the new market.

According to Table 2, the number of new energy vehicles from 2015 to 2022 continues to increase [7]. Considering the impact of the epidemic on the overall growth rate of car ownership, China's demand for new energy vehicles is still rising at a high speed [8]. From the perspective of policy, the two policies of purchase tax exemption for new energy vehicles and unlimited travel have improved the competitiveness of new energy vehicles in the market.

At the same time, there are also many adverse factors affecting the demand for new energy vehicles. For example, the problems of charging piles can become an obstacle to choosing electric vehicles. Both the number and location of charging piles can influence the adoption rate of EVs [9]. Based on the government's decision, only a fixed percentage of parking spaces have been rebuilt as charging spaces. This ratio is not based on actual demand, so there is still some mismatch between supply and demand [10].

According to Table 3, a certain percentage of consumers still choose plug-in hybrid vehicles, which have both gasoline and electric power sources. The reason why pure

electric vehicles have not entered the market on a large scale is that all aspects of technology such as batteries are not mature enough to support the stable operation of cars in various environments. From the research of Zhao and Burke (2023), the current battery is mainly limited by storage capacity and life and other problems can not be stable power supply for a long time. The number of safety accidents in recent years also suggests that the safety issue of electric vehicle batteries also needs to be taken into account [8].

At present, the manufacturing of batteries is mainly divided into positive and negative electrode materials, electrolyte, diaphragm, conductive agent and other aspects [8]. The market segments of labor is relatively detailed, and there are many companies with the same department in each field. Among these companies are both established metal manufacturing companies and emerging technology companies. But with the current technology, the cost of solving existing problems is too high [11]. For now, most companies still choose to increase battery capacity, optimize the insulation layer to ensure that the battery can be used normally. They also solve the current problems by improving the battery performance by solving excess heat energy and improving safety.

To sum up, China's electric vehicle industry is currently in a stage of rapid development, and the initial construction has been basically completed, but there is still a lot of room for development in the optimization of supporting facilities and some major technologies.

2.2 Overview of the new energy vehicle China market

Table 1. Top 5 brands of new energy vehicles in China in 2022^a.

Ranking	Manufacturer	Sales volume (units)	Year-on-year growth (%)	Portion (%)
1	BYD	792734	301.3	29.0
2	SGMW	248426	18.8	9.1
3	Tesla China	206036	47.5	7.5
4	Geely Auto	132887	358.0	4.9
5	Chery	132815	232.9	4.9

^aNote: The data comes from the Passenger Association

Table 2. Top 5 models of China's new energy cars sold in 2022^a.

Ranking	Motorcycle type	Sales volume (Uint)	Year-on-year growth (%)
1	SGMW MINI	188653	19.4
2	BYD QIN	146490	267.4
3	Byd HAN	96950	85.7
4	The Tesla Model3	63909	-24.7
5	Byd Dolphin	58263	-

^aNote: The data comes from the Passenger Association

Table 3. Top 5 models of China's new energy cars sold in 2022^a.

Type	Proportion (%)
Pure electric	82.84
Plug-in hybrid power	17.14

^aNote: The data comes from the passenger China Automobile Dealers Association

3 The development of new energy vehicle industry

3.1 China's electric vehicle existing quantity scale and future forecast

Statistics provided by the China Association of Automobile Manufacturers (CAAM) revealed that China's new energy vehicles have maintained a positive momentum of rapid development, whose rate has ranked first globally for eight consecutive years. Under the dual impacts of policy and market, new energy vehicles continued the trend of explosive growth in 2022, with annual sales exceeding 6.88 million units, whose year-on-year growth is 93.4 percentage, and the market share increasing to 25.6%. All these figures have proven that the new energy vehicles market in China is gradually entering a period of full-scale market expansion. In 2022, 5.365 million pure electric vehicles were sold, rising 81.6 percent compared with a year earlier; the sales of plug-in hybrid vehicles was 1.518 million units, increasing by 1.5 times year-on-year. In general, China's new energy vehicle sales currently account for 25.6% of total new vehicle sales, which means the target of "new energy vehicle sales reaching 20% of total new vehicle sales by 2025" mentioned in the New Energy Vehicle Industry Development Plan (2021-2035) has been accomplished three years ahead of schedule. According to forecasts, global sales of electric vehicles are expected to increase to 11 million units by 2025, with China's share of electric vehicle sales reaching nearly 50 percent of the global market.

The prediction of new energy vehicle ownership is greatly influenced by technological development and policy, so domestic scholars in China mainly use a combination of qualitative and quantitative methods to start the prediction. At present, the scholars have reached the consensus below. From the policy point of view, financial subsidies for new energy vehicle sales are not very significant in promoting purchase intention, and new energy vehicles unlimited obtaining policy and license plate easy-to-obtain policy will have a greater impact on the consumer's willingness to purchase a new energy vehicle car. From the supporting facilities perspective, the better the government's policies on new energy vehicle purchases, charging piles and other supporting facilities are, the more consumers will be motivated to buy. The forecast analysis containing four aspects of price, psychology, vehicle performance, and macro policy, found that Beijing's new energy vehicle industry is still in the development stage, and is highly dependent on policy factors, which is consistent with the situation at the national level.

The White Paper on China's New Energy Vehicle Development Trend 2022 indicates that from 2016 to 2020, the development of the new energy vehicles industry has been greatly promoted on both the supply and demand sides through the man-

agement of "dual credit" and tax incentives. Moreover, the product technology has been significantly upgraded. It can be considered that the new energy vehicle market sales have successfully been driven by the market instead of the policies. The industry has experienced a start-up and a preliminary exploration stage and has been rapidly growing since 2021.

3.2 Overview of new energy vehicle welfare

3.2.1 Adjustment and optimization of subsidy policies. Since the pilot demonstration and promotion of new energy vehicles was launched in 2009, the national institutions represented by the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the Development and Reform Commission [12] and local government authorities have jointly issued several subsidy policies to scientifically regulate the development of new energy vehicles in different periods, increase its market share, and ensure a healthy and sustainable development of relevant enterprises.

Table 4. New energy vehicle welfare policies in China.

Time	Sector	Policy	Main Content	Value
2009	Ministry of Finance, Ministry of Science and Technology	<i>Notice on Pilot Work on Demonstration and Promotion of Energy-saving and New Energy Vehicles</i>	New energy vehicles are prioritized for piloting in the public service sector (including public transportation, rental, sanitation, public service, postal service, etc.) in 13 large and medium-sized cities, including Beijing and Shanghai, and financial subsidies are provided to pilot operating provinces.	Through the implementation of the demonstration and pilot work of new energy vehicles in the field of public services, new energy vehicles have begun to penetrate residents' lives.
2010	Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology, and the Development and Reform Commission	<i>Circular on the Pilot Scheme for Subsidizing the Private Purchase of New Energy Vehicles</i>	Financial subsidies were proposed for the private purchase of new energy vehicles for the first time.	China supported and cultivated emerging industries, sped up technological progress in the automobile industry, and laid a foundation for the smooth entry of new energy vehicles into the consumer market.
2014	Ministry of Finance, State Administration of Taxation, Ministry of Industry and Information Technology	<i>Announcement on the Exemption of Vehicle Purchase Tax for New Energy Vehicles</i>	New energy vehicles are exempted from the purchase tax, while tax and financial incentives for new energy vehicles are constantly being upgraded.	It stimulated consumers to understand new energy vehicles and include them in their priority consumption plans, and further expand the new energy vehicle market.
2017	Beijing Municipal		From 2017, the subsidy	It helped enterprises get

	Bureau of Finance		for new energy vehicles was adjusted to 50% of the central subsidy standard.	rid of "subsidy dependence" and effectively crack down on "subsidy fraud", and ensured the steady and healthy development of the new energy vehicle industry.
2018	Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology, and the Development and Reform Commission	<i>Notice on Adjusting and Improving Financial Subsidy Policies for the Popularization and Application of New Energy Vehicles</i>	Clear provisions have been made on improving subsidy standards, issuing subsidies on a graded basis, and raising the threshold for car models.	It strengthened the core competitiveness of new energy vehicles and improved the quality and efficiency of the industry.
2019	Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology, and the Development and Reform Commission	<i>Circular on Further Improving Financial Subsidy Policies for the Popularization and Application of New Energy Vehicles</i>	Reduce the subsidy on the original subsidy standard for new energy vehicles within the prescribed range.	It marks that the subsidy policy of new energy vehicles has entered a more substantial "declining slope" stage, encourages the survival of the fittest and technological progress of the new energy vehicle market, and implements the long-term market-oriented mechanism.
2019	Beijing Municipal Science and Technology Commission, Beijing Municipal Bureau of Economy and Informatization, Beijing Municipal Bureau of Finance	<i>Notice on the Adjustment of the Relevant Contents of the Administrative Measures for the Promotion and Application of New Energy Vehicles in Beijing</i>	Discontinue municipal financial assistance for purely electric vehicles.	Follow the national strategic orientation to adjust policies, do a good job in the demonstration and leading role of the capital pure electric vehicle market, and return the main driving force of electric vehicle sales to the market.

According to Table 4, the subsidy policies for new energy vehicles effectively activated the potential market of new energy vehicles in the early stage. The sales of new energy vehicles in China continued to rise rapidly from 2015 to 2017. The step-by-step implementation of subsidies and slope reduction policy makes the terminal price of new energy vehicles rise, encourages the industry to transform from "policy-driven" to "market-driven", and contributes to the high-quality development of the industry.

3.2.2 Dual-credit policy focuses on the supply side. Starting in 2021, Beijing strictly implemented the Decision on revising the Measures for the Parallel Management of the Average Fuel Consumption of Passenger Car Enterprises and the Points of New Energy Vehicles. On the one hand, the government encouraged the sales of fuel-efficiency models and regulated the production and import of fuel-efficiency vehicles from 2021 to 2023 to conserve energy and reduce emissions. On the other hand, Beijing actively implemented stricter new energy credit standards, that is, start-

ing from 2019, the credit proportion of new energy vehicles increased by 2% year annually to reach 18% in 2023. The dual-credit policy has built a long-term market mechanism that promote the sales-output ratio of new energy vehicles to drive industrial development [13].

3.2.3 Continuous improvement of infrastructure. In June 2014, the General Office of Beijing Municipal People's Government issued the Action Plan for the Promotion and Application of Electric Vehicles in Beijing (2014-2017), indicating that infrastructure construction should be developed in the direction of networking and facilitation.

In 2016, Beijing Electric Vehicle Charging Infrastructure Special Plan (2016-2020) proposed that by the end of 2020, the construction of charging networks in public areas in the city (excluding mountainous areas) should meet the requirements of an average service radius of less than 5 kilometers, and the private self-use sector should basically realize the requirement of "one vehicle, one pile".

In 2019, the Beijing Municipal Commission of Urban Management issued the Notice on Further Clarifying Operational Centralized Charging and Swapping Facilities, facilitating the process and price level of the operators of charging and swapping facilities, effectively reducing the charging cost of electric vehicle owners [14].

3.2.4 Increased Standardization of Production Scale. With the continuous progress of the industry, the national financial subsidy policy has developed from benefiting all new energy vehicle enterprises and comprehensively expanding the domestic market, to supporting the good ones and strengthening their competitiveness. The goal of building a world-class brand of new energy vehicles, to a certain extent, promoting the production scale threshold of the new energy vehicle industry chain is constantly rising. The requirements for production technology innovation and level improvement have reached a new level.

The Standard Conditions for the Automotive Power Battery Industry, published in 2016, set higher standards for the production scale of enterprises producing ancillary products for electric vehicles, and clearly stipulated the annual production capacity of enterprises requiring the production of lithium-ion power batteries and the annual production capacity of system enterprises.

In January 2017, the Ministry of Industry and Information Technology made clear provisions on the management and product quality access standards for new energy vehicle production enterprises, aiming to improve the access threshold of enterprises in terms of R&D capabilities, production consistency capabilities, and product safety assurance capabilities. The regulation requires enterprises to increase capital investment and expand production scale to a certain level.

3.2.5 Preferential policies for new energy vehicles relating to purchase restriction. Since the implementation of the purchase restriction policy in 2011, the allocation quota of Beijing small bus index has been changing, and the allocation tilt policy of new energy index has become more and more obvious. The proportion of

new energy small cars quota has gradually changed from 13.3% in 2014 to 60% from 2018 to 2021. New energy vehicles have a higher acquisition rate and a short waiting time. This policy provides a beneficial supplement to the realization and acceptance of the popularization of new energy vehicles. Statistics show that in February 2015, the number of individual index applications for new energy passenger cars in Beijing was only 2139 units, whereas in December 2021, the number of effective application code of the new energy passenger car index in Beijing was 421,536.

4 Analysis of survey on usage patterns of automobile users

The team employed a combination of offline and online methods to conduct a community-based survey targeted at both residents of Beijing and the new energy industry. Over 300 valid questionnaires were collected. The survey provided insights into the current ownership of new energy vehicles among residents, an overview of the energy consumption advantages of these vehicles, the current industry policies, planning, overall audience status, and future predictions. Considering the current dual-carbon context in China, the following summary analysis was conducted on the economic and environmental impact factors affecting the development of the new energy vehicle industry.

4.1 New energy vehicle ownership

Based on the valid analysis of our survey, the age group of car owners is predominantly concentrated between 45 and 60 years old (approximately 56%). The remaining age groups are distributed as follows: 15% for 31-45 years, 22% for 18-30 years, and approximately 6% for those under 18 or over 60.

Regarding family vehicle ownership, around 80% of households or individuals own only gasoline-powered cars, with about 9% having only new energy vehicles or a combination of both gasoline and new energy vehicles. Among the surveyed, 80% of the data indicate that families own 1 to 2 gasoline-powered cars, around 8.7% own 1 new energy vehicle, while approximately 90% of families do not own any new energy vehicles. About one-third of respondents stated that they had sold their gasoline cars and subsequently purchased new energy vehicles. The majority of respondents (about 2/3) expect the price of new energy vehicles to be between 10 to 30 yuan, with approximately 23% expecting prices between 5 to 10 yuan, 10% expecting prices between 30 to 50 yuan, and almost 0% expecting prices above 50 yuan. About half of the respondents living near new energy vehicle experience stores, while 80% have electric vehicle charging stations nearby, with 30% mentioning that the charging stations are slightly far from their residence.

4.2 New energy vehicle energy consumption

On average, users of gasoline-powered cars drive varying distances daily, with 24.8% driving between 0-5 kilometers, 20.8% between 5-10 kilometers, 26.8% between

10-20 kilometers, 18% between 20-40 kilometers, and around 10% over 40 kilometers. Compared to gasoline-powered cars, users of new energy vehicles drive longer distances on average, mainly concentrated in the ranges of 5-10 kilometers, 20-40 kilometers, and over 40 kilometers. About half of the respondents drive more than 20 kilometers per day. The users of gasoline-powered cars mainly own sedan and SUV models, with engine displacements concentrated between 1.0 and 2.4L. Among them, 1.5-1.8L accounts for approximately 43.6%, 2.0-2.4L for around 30%, and 1.0-1.5L for about 20%. The average fuel consumption per 100 kilometers for gasoline-powered cars is concentrated between 5-12L, with 5-8L accounting for 36.8% and 8-12L for 51.6%.

4.3 Popularization of new energy vehicle policies

According to Figure 1, about 75% of respondents have received information or heard about the main incentive policies and benefits for new energy vehicles. Private purchase subsidies and exemptions from new energy vehicle purchase taxes account for a high proportion, around 50%. Approximately 24.5% of respondents are aware of the policy on new energy vehicle quota allocation, while about 10% are aware of the "dual credit" management policy and the special planning for electric vehicle charging infrastructure in Beijing. Around 59% of respondents received welfare guarantees when purchasing new energy vehicles, and 62% believe that the current welfare guarantees for new energy vehicles are attractive. About 92% of respondents believe that the country will vigorously promote new energy vehicles in the future, and around 81% plan to purchase new energy vehicles as a means of transportation in the future.

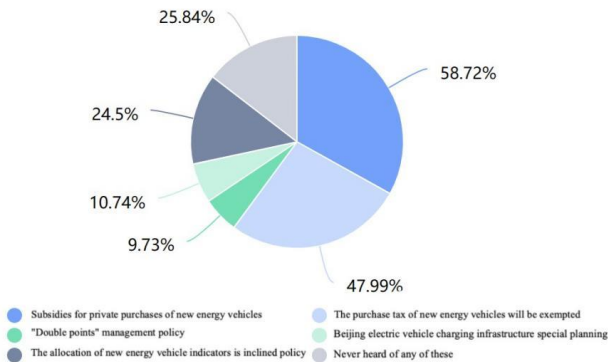


Fig. 1. Awareness of Relevant Policies and Benefits for New Energy Vehicles.

4.4 Popularity of new energy vehicles

In commuting statistics, gasoline-powered cars and the subway are the preferred choices, with slightly lower preferences for buses, bicycles, and walking compared to gasoline cars and the subway. The usage rate of new energy vehicles is the lowest, accounting for about 13%. In addition to commuting, the choice of new energy vehicles remains low, at 12%. About 35% of respondents plan to replace or purchase motor vehicles in 3-5 years, with around 20% planning to do so in 1-2 years or 5-10 years. Approximately 19% of respondents do not plan to replace or purchase motor vehicles. About 68% of respondents hope to replace or purchase new energy vehicles, while approximately 31% prefer traditional gasoline vehicles. According to Figure 2, most respondents believe that choosing new energy vehicles can save energy, reduce emissions, protect the environment, and offer high cost-effectiveness with many policy welfare subsidies. In addition, 14% of respondents believe that the longer range of new energy vehicles compared to gasoline cars is a reason to choose them. When given the choice between new energy vehicles and gasoline cars at the same price, approximately 56% of respondents choose to purchase new energy vehicles, representing an increase of about 13% compared to those choosing gasoline cars. The majority of respondents believe that new energy vehicles have higher safety levels. Compared to gasoline cars, the perceived advantages of new energy vehicles are mainly in terms of high cost-effectiveness, attractive appearance, and low driving noise, while most respondents believe that gasoline cars have better safety and range capabilities. About 74% of respondents believe that in the future, new energy vehicles will replace gasoline cars on a large scale.

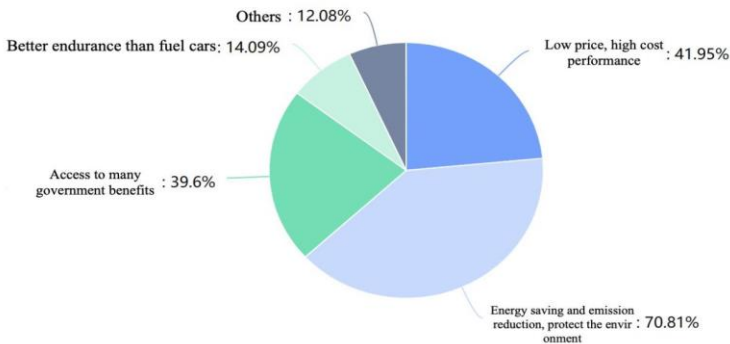


Fig. 2. Analysis of Advantages of New Energy Vehicles.

5 Conclusion

Overall, according to the research results, the electric vehicle industry in China is in a stage of rapidly developing with a completed initial construction. However, there is still heavy work needed to be done in the optimization of supporting facilities and some major technologies. Meanwhile, the new energy vehicle market has been transformed from policy-driven to market-driven, stepping into rapid growth period after

experiencing an embryonic and preliminary exploration period. In addition, for the first ranking in the world of car production, the Chinese government sees a huge market potential and has timely adjusted the industry structure of automobiles by taking a series of actions such as energy efficiency improvement and emission reduction innovation. Based on the industrial research consequence, various policies have been promulgated by the Chinese government, covering multiple dimensions like industrial policies, development plans, demonstration projects, financial subsidies and tax incentives. It is obvious that the government has put in practical efforts to achieve sustainable planning and development strategies.

It's reported that the life cycle carbon emissions of new energy vehicles can be reduced by 25% to 45% compared with traditional petrol energy vehicles. Combined with the considerable future amount of new energy vehicles forecast, the carbon emission reduction contribution of the new energy automobile industry can reach 45%-50% of the whole society in 2050, and its economic benefits have been verified in the United States and other developed countries, with huge market prospects and development potential.

However, the further development of China's new energy vehicle industry still faces great challenges. Firstly, there is still a gap in the internationalization of Chinese new energy vehicle industry and related technology benchmarks. Secondly, taking Beijing, the representative city of China's advanced development, as an example, the comprehensive evaluation of the social acceptance of new energy vehicles is only about 60%. Therefore, other cities are likely to show a lower evaluation index, which will become a major obstacle to the new energy vehicle industry, indicating that large-scale application and industrialization popularization still have a long way to go. Finally, if the new energy vehicle industry wants to achieve absolute green, it will also be related to many other industries. For example, the proportion of renewable energy in power generation and consumption must increase. Otherwise, if the electricity comes from burning fossil fuels, the environmental benefits of new energy vehicles will not be realized.

In view of the above development dynamics and practical challenges, combined with the feedback of car users in the data survey, this paper puts forward the following development suggestions. First, at the technical level, although the R & D productivity of China's new energy vehicles has improved, the breakthrough of core technologies has yet to be invested in greater capital. The energy storage equipment, motors, system integration technology and applied batteries in China still have a certain gap with the international leading level. Second, from the industrial level, the industrial chain of China's new energy is not mature enough, which cannot provide a favorable environment for the new energy automobile industry. There is still a certain gap in the upstream industry (power battery industry) and the downstream industry (hydrogenation station industry, charging pile industry) compared with developed countries such as Germany and the US. In this regard, the government needs to encourage and improve the development of related industries. Third, at the societal level, in order to further enhance the recognition and acceptance of new energy vehicles of car users, it is necessary to promote energy education and raise public awareness regarding new energy sources. Additionally, for the full realization of the potential

within the new energy vehicle market, continued implementation of relevant subsidy policies by the government remains essential. This should be accompanied by continuous improvement in basic infrastructure facilities, reasonable pricing strategies, product diversification, and other dimensions that can facilitate a shift in consumer attitudes and habits. By doing so, greater environmental and economic benefits towards achieving sustainable urban transportation can be generated in the future.

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