

Research on the Development of Global New-Energy Vehicle Industry Under the Goal of Carbon Neutrality

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Abstract: As a pioneer in energy conservation and environmental protection, new energy vehicles also play an important role in reducing carbon dioxide emissions. Carbon neutrality will become a long-term measure to reduce greenhouse gas emissions in the future, and the new-energy vehicle industry should develop a path that is more in line with the goal of carbon neutrality

Keywords: New-energy vehicles; Development path

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1. Introduction

Carbon neutrality involves assessing and quantifying the carbon dioxide emissions produced by organizations, individuals, and businesses during their operations. This is followed by implementing energy-saving measures, emission reductions, and tree planting over a specific timeframe to offset these emissions, thereby decreasing overall carbon dioxide emissions. The concept of carbon neutrality advocacy has been gaining support from many countries. From January 29 to February 2, 2007, the United Nations Intergovernmental Panel on Climate Change (IPCC) held meetings in Paris. After the meetings, global climate change assessment reports pointed out that about 90% of the climate change in the past 50 years may be caused by human activities. In July 2013, the International Air Transport Association introduced the “2020 Carbon Neutrality” initiative for the aviation sector, which requires airlines worldwide to cover emissions exceeding the set quota post-2020. Furthermore, in October 2018, the United Nations Intergovernmental Panel on Climate Change urged all nations to proactively combat global warming, aiming to restrict it to a 1.5 °C rise^[1].

Carbon neutrality is the main component of the United Nations Climate Change Conference and the environmental protection implementation measures of various countries in recent years, and it is the main means for human to reduce carbon dioxide emissions. As a pioneer of energy conservation and environmental protection, new-energy vehicles also play an important role in reducing carbon dioxide emissions. Carbon neutrality will become a long-term measure to reduce greenhouse gas emissions in the future. The global new-energy vehicle industry must formulate a path that is more in line with the goal of carbon neutrality^[2], which involves five aspects.

2. Adhering to the development line with innovation as the core

Innovation is the fundamental driving force for the sustainable development of the industry and an important way to realize the leapfrog development of the new-energy automobile industry. The fact that global sales of new-energy vehicles have soared in 2020 proves that technological innovation is the driving force behind industrial development^[3]. Therefore, this means that continuous innovation and development of new technologies can ensure the overall development of the new-energy automobile industry

2.1. Technological innovation

The early stages of the new-energy vehicle industry saw rapid development, with sales surging since 2015. These sales figures have notably outpaced the growth rate of overall vehicle sales. However, this growth is largely attributed to robust industrial support policies playing a pivotal role. Notably, post-subsidy vehicle prices hold a significant advantage over traditional fuel vehicles, delivering exceptional cost-effectiveness and attracting consumer interest. Due to excessive reliance on subsidies, companies generally lack the motivation for technological innovation. The core technologies for new-energy vehicles are still in an immature stage, particularly in areas such as range, electronic control management, and safety protection. These aspects are yet to reach advanced technical levels. Manufacturers have relied heavily on pricing advantages to compensate for these technological gaps. However, starting from 2017, major global new-energy vehicle producing countries have progressively reduced subsidies. As a result, new-energy vehicle companies are now compelled to hasten the upgrading of their products. Before 2017, the mileage of pure electric vehicles was generally around 300 km, which was far from the mileage of fuel vehicles. After 2017, the energy density of power batteries began to increase rapidly, and the level of electronic control continued to be optimized. In 2018, the battery life of pure electric vehicles has generally reached 400–500 km, and some models can even reach 550 km. Facing challenges such as bottlenecks, innovation gaps, and a slowdown in advancements, the range and acceleration performance of new-energy vehicles have remained stagnant. Simultaneously, there has been a sharp reduction in subsidies for new energy vehicles. The combined effect of these two factors has significantly impacted global new energy vehicle sales. In 2019, the annual growth rate of global new energy vehicle sales was only 9.5%, falling below 10% for the first time, far lower than the previous growth rate, and was at the lowest point in recent years. As a result, new-energy vehicle companies have learned from the experience and started prioritizing technological innovation. In 2020, the technology of new-energy vehicles showed significant improvements, with the maximum range generally reaching 600 km, and the Xpeng P7 model had a range of more than 700 km^[4]. Acceleration levels have also seen significant improvements. For instance, the BYD Han EV has achieved a 0–100 km/h acceleration time of under 4 seconds for commercially available pure electric family cars. Despite the global decline in car sales due to the COVID–19 pandemic in 2020, new energy vehicles remained unaffected, experiencing a sales increase of 46.6%. This marked the first time that sales exceeded 1 million units. Returning to a high-growth era amid decreasing subsidies is a challenge. Technology advancements have emerged as a crucial factor driving this progress.

2.1.1. Power battery

The development trend of battery technology determines the overall development trend of the new-energy vehicle industry as it is the core technology of new energy vehicles. In recent years, the energy density of power batteries has achieved new breakthroughs. Companies such as BYD, Ningde Times, AVIC Lithium Battery, and Panasonic have been actively developing batteries with high energy density. The American luxury pure electric car Lucid Air was launched in October 2021, with a battery life of 832 km. GAC

AION LX Plus pure electric SUV had a range of 1 008 km in the catalog of recommended models for the promotion and application of new-energy vehicles announced by the Ministry of Industry and Information Technology of China in November 2021, and was the world's first pure electric vehicle with an energy density exceeding $200 \text{ Wh} \cdot \text{kg}^{-1}$ car at that time^[5].

Car battery manufacturers have been improving battery performance and battery safety. In March 2020, sales of BYD Han had been rising steadily since its launch, and their blade battery passed the acupuncture test. In March 2021, GAC Aian's magazine battery system achieved a breakthrough in safety technology. The power battery pack demonstrated resistance to catching fire upon being needled, successfully passing the acupuncture thermal diffusion test. In September 2021, Great Wall Motors introduced the Dayu battery, which exhibits exceptional safety features. It remains non-explosive and non-flammable even if single or multiple batteries experience thermal runaway at any position. Additionally, this battery technology provides comprehensive coverage of the battery's chemical system^[6]. In the future, cars will provide users with a safer driving environment, and the safety of power batteries will be significantly improved.

The charging and swapping technology has also been improving and developing. Brands like Xpeng, Tesla, and NIO can charge up to 80% capacity in 30 minutes with charging power of 180–250kW. Porsche achieves 80% charge within 15 minutes, utilizing charging power up to 350kW. Although not as swift as refueling for conventional vehicles, innovations such as BAIC New Energy and NIO's battery replacement stations can replace a car battery in just 5 minutes. This trend indicates a potential solution for insufficient mileage in the future^[7].

2. 1. 2. Electric control system

The electronic control system is control center of new-energy vehicles. Electronic control technology has also been developing rapidly in terms of using new materials. Silicon carbide power modules have begun to be used in pure electric vehicles. BYD, Tesla, Weilai, Infineon, Mitsubishi, "CRRC Times" and Hitachi are developing new Silicon carbide power module system for energy vehicles. The use of silicon carbide power modules is the future development trend of electronic control technology. Silicon carbide power modules can significantly improve the overall efficiency and service life of electronic control systems.

As a transitional model for pure electric vehicles to replace fuel vehicles, hybrid vehicles can effectively solve the problem of range anxiety. However, their energy consumption during power-feeding often surpasses that of equivalent fuel vehicles, leading to lower long-term sales. New breakthroughs have been made in recent years. The January 2021 release of BYD DMI's super hybrid technology achieved remarkably low fuel consumption during power-feeding, effectively addressing the previous issue of high fuel consumption^[8]. DMI models immediately became the best-selling models in the market, and the backlog of orders and the short supply had boosted the overall sales of hybrid vehicles.

2. 1. 3. Drive motor

The drive motor is also the core component of the new-energy vehicle. It directly drives the vehicle. During the initial phase, it delivers maximum torque, resulting in strong acceleration performance that surpasses similar-grade fuel vehicles. Nevertheless, the motor's torque diminishes rapidly during high-speed operation. In recent years, drive motor output power has steadily risen, driven by ongoing innovation in materials, performance, and systems. For instance, the 2019 Porsche Taycan pure electric coupe features a rear drive motor with an impressive power of up to 476PS, a substantial increase from the 150PS rear drive motor that come out in 2018^[9].

The early drive motors used round-wire materials. After 2015, flat wire motors began to replace traditional round-wire motors, becoming the development trend of drive motors. Most of the new-energy models on sale generally use single/dual motor configurations. Some models are even equipped with three or four drive motors, which further improved the power and performance of the vehicles, and offered products at different price range^[8]. Asynchronous motor and permanent magnet synchronous motor both come with their own advantages and disadvantages, and the combination of the two drive motors optimizes the overall performance. Companies such as Weilai and Tesla have launched models equipped with permanent magnet synchronous motors and asynchronous motors, and the overall performance has been significantly improved compared with the previous models.

2.1.4. Auxiliary technology

In addition to the core technology of new-energy vehicles, auxiliary technologies have also advanced by leaps and bounds. Low drag coefficient, lightweight body, concealed exterior decoration, heat-pump air conditioner are all auxiliary technologies that have been widely used in the field of new-energy vehicles. The reduction in vibration and noise of the drive motor, combined with the integration of intelligent network technology, has enhanced the competitive edge of auxiliary technology's core products. This has led to significant enhancements in functionality, efficiency, handling, safety, environmental friendliness, and comfort. As a result, the overall competitiveness of energy vehicles has seen substantial improvement.

2.2. Model innovation

Technological innovation is the driving force leading the development of the new-energy automobile industry, but technology alone is not enough, and marketing strategies are also important. In recent years, many new business models have emerged in the new energy vehicle industry.

2.2.1. Direct sales model

In the era of traditional fuel vehicles, the 4 S store sales model integrating sales, service, spare parts (as per industry norms), and survey occupies the mainstream, and consumers generally purchase vehicles on the spot. However, since 4 S stores are generally operated by intermediary agents, it is difficult for production companies to supervise, so they have been criticized for problems such as arbitrary charges, mandatory configuration, bundled sales, and defrauding consumers. In recent years, with the rapid growth of Internet technology, mobile payment methods have gained widespread acceptance. Given the high level of intelligent network connectivity in pure electric vehicles, their compatibility with online services is remarkable. Manufacturers such as Ideal, Xpeng, Tesla, NIO, and WM Motor have embraced online sales models that are centered on direct sales (online purchases). This approach facilitates the entire process, including ordering, payment, delivery, and after-sales service, effectively eliminating intermediary 4 S store agent involvement. This shift ensures complete transparency and openness in pricing. In this mode, consumers can freely choose configurations on the basic model to achieve exclusive personalized customization. Besides, major companies have also set up showrooms in the central business district of the city for display and test drive only, so as to increase their popularity and attract potential customers. The direct sales model has effectively solved the long-standing problems of traditional 4 S stores. However, since it is a new thing, it will take time to gain public acceptance. In the short term, it will have limited impact on the 4 S store model that has existed for many years. However, due to the Covid-19 pandemic 2020, strict anti-pandemic measures have led to the closure of many 4 S stores, making it impossible for consumers to purchase products. However, the direct sales model can realize complete contactless online purchases, and new cars can be sold even during the pandemic prevention and

control period. As a result, Tesla achieved remarkable global sales of 499,500 vehicles in 2020, marking a 35.8% year-on-year increase. Following suit, traditional fuel vehicle manufacturers began to emulate the direct sales approach, establishing premium pure electric vehicle sub-brands that adopted the same model. Notably, SAIC Motor's R Automobile and Geely Group's Jifan Automobile Company were established, signifying a transformative shift in the sales model within the new energy automobile industry^[9].

2.2.2. "Vehicle-electricity separation" business model

In the early days, the battery of a new-energy vehicle was fixed on the chassis of the car, which made it difficult to replace, and the batteries were expensive, with a limited range and poor appearance. The present battery replacement technology enables the rapid disconnection of vehicles from power batteries, giving rise to a new business model known as "vehicle-battery separation." This concept first emerged in 2010 when State Grid introduced the "vehicle-electricity separation" model, initiating pilot projects with battery-swapping taxis from Haima and Zotye. NIO introduced a battery rental program for ES8 in late 2017. Subsequently, in July 2018, BAIC New Energy launched the "vehicle-electricity separation" solution. Weilai followed suit, introducing an upgrade plan in September 2019 allowing users to switch from a 70 kW-h to an 84 kW-h battery pack. In 2020, Weilai launched the WOkW-h battery pack. By December 2021, Weilai unveiled a flexible battery upgrade system, permitting users to enhance battery packs on a monthly, annual, or permanent basis, effectively augmenting the range of new energy vehicles.

2.2.3. Customization of operating vehicles

The operating costs of operating vehicles need to be strictly controlled. In recent years, the rising oil price has caused the transportation cost to rise year after year, making the operation of commercial vehicles difficult. Pure electric vehicles typically offer a slightly shorter range compared to equivalent fuel vehicles. However, their usage costs are considerably lower than gasoline, diesel, or natural gas vehicles, resulting in significant reductions in operational expenses. The operation mode of fixed locations enables it to plan routes in advance, conveniently replenish energy, and avoid mileage anxiety, making pure electric vehicles a better alternative. In recent years, many countries and regions around the world have begun to gradually convert commercial vehicles into pure electric vehicles. Taiyuan City, Shanxi Province, China replaced all 8,292 taxis in the main urban area with pure electric vehicles (BYD e6) at the end of 2016, becoming the first city in the world to achieve 100% electrification of taxis. Dubai, UAE took the lead in replacing taxis with Tesla pure electric vehicles in 2017, and received good feedback. The proportion of electric taxis in Shenzhen City, Guangdong Province, China have reached 98.57% in January 2019, which is more than 21,000 pure electric taxis. A world-renowned taxi-hailing application developer, Uber, began to popularize pure electric vehicles globally in 2017 by cooperating with automobile companies and subsidizing drivers. The United States, Norway, the United Kingdom, France, Canada, Germany, Japan and other countries has also begun to gradually replace fuel buses with pure electric buses. The rapid promotion of new-energy vehicles has led more and more companies to devote themselves to this promising field. Historically, automobile manufacturers and operating companies functioned as separate buyers and sellers, operating in isolation. The rise of intelligent network connectivity in new energy vehicles has empowered manufacturers to autonomously establish remote network systems for vehicle operation and management. E-hailing services have connected the two aspects of automobile production and operation. In recent years, original equipment manufacturers have independently established e-hailing companies. For example, CAO CAO Travel by Geely, Shouqi Car-hailing by BAIC, Xiangdao Travel by SAIC and other e-hailing brands. E-hailing platforms have broken the monopoly of taxis and benefited

consumers. In addition to that, vehicle manufacturers also cooperate deeply with car-hailing companies. In June 2018, 500 dolphin buses customized by Yinlong New Energy for Zhuhai were officially put into operation, where sales were only open to Didi-registered online car-hailing operators. In addition, BYD also produces customized pure electric buses for Japan, the United Kingdom, Israel, and other countries. In the future, more customized new-energy commercial vehicles will be put into the market. Technological and model innovations have propelled the new energy vehicle industry into a qualitative leap. This internal enhancement is crucial, especially in the era of carbon neutrality. Currently, the majority of global new energy vehicle companies have set up independent research and development systems for their products. It is imperative to remain committed to the path of innovation and drive the sustainable growth of the new energy vehicle sector.

3. Expanding the industrial scale, which is guided by with the market demand

In the early stage of the development of the new-energy vehicle industry, due to immature technology and insufficient market research, some traditional fuel vehicle companies directly transformed existing fuel vehicles into new-energy vehicles in order to save costs and energy, and obtain subsidies at the same time. The most typical model is the “oil-to-electricity” model released by Volkswagen. Volkswagen has launched pure electric versions of fuel vehicles such as LaVida, Golf, and Bora. Fuel vehicles are typically designed considering the dimensions and features of their engines, including factors like volume, structure, and intake/exhaust systems. Consequently, they often feature a ventilated front face, a shorter wheelbase, and limited internal space. However, due to these constraints, accommodating a shorter wheelbase becomes challenging. The large-capacity battery and the ventilation intake grille affect the drag coefficient, both of which affect the range of pure electric vehicles to varying degrees, and the irregular arrangement will lead to unequal weight distribution at the front and rear of the vehicle and an imbalance in the center of gravity, which will affect driving experience. Moreover, unreasonable motor and battery layout will also cause safety problems. As a result, Volkswagen’s electric vehicles frequently encounter issues related to limited power output and short battery life. Other major automakers such as Toyota, Mercedes-Benz, BMW, and SAIC have introduced similar models, which all led to the same challenges and outcomes. The “oil-to-electricity” approach reflects traditional fuel vehicle manufacturers’ attempts to address the new energy vehicle market, which led to unsuccessful results. In contrast to the speculative “oil-to-electricity” approach favored by traditional fuel vehicle manufacturers, new energy vehicle companies are more inclined to adopt platform-based strategies, establishing dedicated platforms for their electric vehicles. Notably, companies like BYD, Great Wall, Geely, and Mercedes-Benz from the fuel vehicle sector have introduced their own exclusive platforms for new energy vehicles. This trend is also evident in pure electric vehicle manufacturers such as Tesla, NIO, Xpeng, and Ideal. As a trailblazer in the global new energy vehicle landscape, BYD has developed a comprehensive platform system, featuring the BNA architecture encompassing two key platforms: the DM platform and the e-platform. The DM (Dual Mode) platform is dedicated to hybrid models, forming the foundation for popular hybrid models like Tang DM, Song DM, and Qin DM. At the beginning of 2021, BYD launched a new DMI model, subdividing the DM platform into DMP models focusing on performance and DMI models focusing on energy saving; the e platform focuses on pure electric models, Tang EV, Song EV, Qin EV, Yuan EV, etc. The hot-selling pure electric models of the Dynasty series and e-network models such as e1 and e2 all come from this platform. At present, both DM platform and e-platform have developed to the third generation, namely DM 3.0 and e-platform 3.0, and BYD’s platform system has been gradually improving. In addition, NIO’s NT platform, Xpeng’s SEPA platform, Geely’s SEA’s vast architecture, Great Wall’s ME platform, and Mercedes-Benz’s EVA platform are all exclusively pure electric vehicle

platforms. Platform-based models typically exhibit characteristics such as a streamlined front face and an extended wheelbase for vehicles of the same category. These traits maximize the inherent benefits of pure electric vehicles, resulting in compelling products that are both market-competitive and well-aligned with consumer preferences. Notably, platform products have become the driving force behind the substantial sales of new energy vehicles in recent years. Looking ahead, adopting a platform-based approach is poised to become the primary strategy for new energy vehicle companies, enabling them to consistently broaden the industrial scope of new energy vehicles.

4. Improving the industrial security system and the construction of related supporting facilities

Since the development of the new-energy vehicle industry, the technical level and production quality of the product itself have been significantly improved, which is almost at par with fuel vehicles. New-energy vehicles even has great advantages in terms of acceleration performance, intelligent network connection, and noise, vibration, and harshness. This resulted in a rapid growth in the sales of new-energy vehicles. However, the development of modern industries is often a systematic chain development where all links are an indispensable part of the development system. Problems in any link will affect the development of the industry as a whole. Supporting industries are often ignored because its development generally has limited impact on the overall industry. One major hurdle is the lack of adequate charging and swapping facilities, which hampers the industry's growth. As global sales of new energy vehicles continue to rise, it is essential to tackle these challenges by considering several approaches.

4.1. Formulating relevant targeted plans and policies

During the initial phase of the new energy automobile industry's development, various countries with major production and sales have implemented their own industrial plans and supportive policies. The industry's sales have surged due to a combination of these plans, policies, and its inherent growth. However, the lack of attention to supporting infrastructure by both governments and enterprises has also created potential challenges for the industry. The current situation of lagging development of charging and swapping facilities has made the governments of major producing and selling countries begin to pay attention to and formulate relevant plans and policies. In terms of infrastructure development, it's evident that supporting facilities hold the same significance as the vehicles themselves. While countries like the United Kingdom, Norway, and Japan have introduced plans for charging facilities, there's a notable absence of targeted plans or policies for new energy vehicle supporting infrastructure in many nations. As a result, the progress in constructing and enhancing charging and swapping networks remains quite constrained. The main production and sales countries of new energy vehicles should introduce plans and policies for supporting facilities as soon as possible, to solve problems such as parking difficulties, property difficulties, and fuel vehicles occupying charging spaces, and promote the construction of charging and swapping networks.

4.2. Speeding up the construction of charging and swapping networks

Global public charging piles have grown rapidly in recent years. As of the end of 2020, the number of public charging piles in the world has exceeded 1 million, and the compound annual growth rate in the past seven years has reached 32%, far exceeding the growth rate of gas stations. The main reason is that the development of the fuel vehicle industry has been highly mature. The demand is currently close to saturation, but the increase in number of charging piles is still significantly lower than the annual growth rate of new energy vehicle sales. The vehicle-to-pile ratio of new energy vehicles has remained high in recent years. The current vehicle-to-pile ratio in major production and sales countries exceeds 5 : 1,

which has begun to restrict the popularization of new energy vehicles. Primarily, new energy vehicle companies are focusing on developing their own networks. Tesla, as a pioneer in charging infrastructure, stands at the forefront of global progress in network expansion. By the conclusion of 2020, Tesla had deployed over 20,000 supercharging stations worldwide, spanning across six continents. It is currently the world's largest single manufacturer charging network. BAIC, NIO, Xpeng, BMW, Porsche, and other companies are actively developing their own charging and swapping networks. BAIC and NIO, as enterprises mastering the technology of battery swapping, are also laying out the construction of swapping stations. In addition, power equipment companies such as State Grid and Telecom are also vigorously building a network of public charging piles. With the joint efforts of vehicle and power equipment manufacturers, the construction of the charging network has made great progress, but it still lags behind the sales growth of new energy vehicles^[10]. In October 2021, the Ministry of Industry and Information Technology of China issued the "Notice on Launching the Pilot Program of the Application of New Energy Vehicle Battery Swap Mode" and decided to start the pilot work of the new-energy vehicle battery swap mode. The support of relevant policies will further accelerate the construction of the battery swap network.

4.3. Improve the scrapping and recycling of power batteries

After long-term use, the electrolyte activity of the power battery will weaken. The lifespan of an electric car battery is 4 – 6 years, and the lifespan of electric commercial vehicle is even lower, at only about 3 years. As the number of vehicles increases year by year, the number of scrapped power batteries for new energy vehicles will also increase sharply.

Toyota is the first company in the world to produce hybrid vehicles and has been in this field for a long time. Its nickel metal hydride battery recycling and processing system has been established as early as 1998. In 2009, Toyota began to establish recycling guidelines in countries selling hybrid vehicles. In 2010, Toyota extended the battery recycling agreement to ensure the hundred 100% recycling. In 2012, Toyota began to recycle rare earth materials for motors. In 2013, Toyota began to try the cascade utilization of Ni-MH batteries. Toyota's first established a recycling network, followed by evaluating recycled batteries to ascertain their characteristics. Subsequently, the processing methods were categorized into three types: cascade utilization, integration into the maintenance system, and dismantling. This approach refines batteries based on their specific situations, leading to a significant enhancement in battery utilization rates^[11]. In recent times, companies such as Volkswagen, BMW, and GM have also initiated efforts to set up systems for recycling used batteries.

Reprocessing and re-selling scrapped batteries can not only save production costs, but also increase income. At the same time, it also solves the problem of unused scrapped power batteries in society, and realizes the recycling and sustainable utilization of resources in the entire industrial chain.

5. Determining a suitable development path

New energy vehicles have been promoted and popularized in more than 40 countries around the world, covering six continents. Nonetheless, the new energy vehicle industry's development scale, level, and trajectory vary, resulting in distinct strategies and paths. China, for instance, boasts an advanced new energy vehicle research and development prowess, coupled with relatively abundant domestic raw material resources catering to the needs of these vehicles. Plug-in electric vehicles and hydrogen fuel cell vehicles have been developing rapidly, covering a relatively complete range of models. The United States and Germany have developed new-energy vehicle technology, but there has been no development in the field of battery and hydrogen fuel cell vehicles, and the development of plug-in electric vehicles is the main focus. France is also yet to develop batteries and hydrogen fuel cell vehicles, with pure electric being the main

trend for development. Japan's battery industry is well developed, but due to the country's special terrain conditions and long-term insufficient power supply, only ordinary hybrid vehicles and hydrogen fuel cell vehicles have been developed, along with plug-in vehicles. South Korea's vehicle battery industry is also well-developed, but they entered the plug-in electric vehicle sector later. Consequently, Korea predominantly focuses on hydrogen fuel cell vehicles, with some pure electric vehicles. In contrast, countries like Norway, the United Kingdom, Sweden, the Netherlands, and others have relatively less robust new energy automobile manufacturing sectors. However, their emphasis lies in promoting and popularizing these vehicles, yielding impressive outcomes. On the other hand, emerging countries in the new energy automobile industry, such as Malaysia, Thailand, Singapore, Mexico, Australia, South Africa, and Brazil, have yet to formulate distinct development paths according to their own attributes, leading to slower industry growth^[12]. The main production countries should continue to maintain and maximize their respective advantages, and develop sustainably according to their own characteristics; while emerging countries should find their own positions as soon as possible and formulate targeted development routes to achieve rapid development.

6. Strengthen coordination and cooperation to promote the common development of global industries

Today's industrial collaboration includes not only collaboration with other external industries, but also intra-industry collaboration; only by optimizing the collaborative development mechanism within the industry can the internal development efficiency of the industry be improved. The current development among regions and industrial chains is uncoordinated, which need to be solved from two aspects.

6.1. Regional coordinated development

The new-energy vehicle industry has experienced rapid growth in recent years, yet it still lacks a cohesive and unified development model. Even though large regional cooperation organizations such as the European Union and ASEAN have issued relevant plans and policies to promote the joint development of the new-energy vehicle industry, due to great differences in politics, economy, and culture in various countries, the level of industrial development is still not the same. Furthermore, the level of industrial specialization within integrated cooperation organizations is relatively low, leading to challenges in formulating specific measures for driving industrial development. As a result, the implementation of plans and policies often faces limitations and lacks impactful outcomes. Although major production countries such as China-Germany, the United States-EU, and Japan-South Korea have established new-energy vehicle industry development alliances, the scope of influence is small, and in the end they still cannot effectively promote the sustained and rapid development of the global industry^[13].

The new energy vehicle industry should actively respond to this situation. There has been no professional new-energy vehicle industry cooperation organization in the world. The main production and sales countries should take the lead in planning and establishing global industrial cooperation organizations such as industry alliances and cooperation forums to strengthen international cooperation and promote the common development of new-energy automobile industries in all countries. New-energy vehicle production and sales countries such as China, the United States, Germany and other countries should play a leading role in their respective continents, take the lead in establishing inter-regional new energy vehicle industry integration cooperation organizations, and promote the development of regional new energy vehicle industries.

6.2. Coordinated development of industry chain

The disconnection and fragmentation of the industrial chain has continued to hinder the development of the

global new-energy automobile industry in recent years, and there have even been serious consequences in which upstream and downstream supply problems have led to the suspension of production of related companies. The reason is that all parties in the industrial chain develop independently and lack coordination, and one party may benefit temporarily, but in the long run, it is the industry as a whole that is ultimately damaged. In recent years, new-energy vehicle industries around the world have begun to realize this problem, and various companies have gradually strengthened their collaborative development through industrial chain cooperation, shareholding, and acquisitions: CATL, LG, Panasonic, and other battery companies have established a solid cooperative relationship with a number of new-energy vehicle companies to break through the industrial chain barriers between autopart companies and vehicle companies. The deep cooperation between German Volkswagen, BMW, Mercedes-Benz and other vehicle companies and Bosch, ZF, Continental, and other autopart companies in the field of new-energy vehicles has promoted the rapid development of the country's new energy vehicle industry. BYD has become the world's first enterprise that integrated battery with new-energy vehicle manufacturing^[14]. Lithium product giants such as Tianqi Lithium Industry and Ganfeng Lithium Industry have successively acquired large lithium mines around the world and started to independently develop batteries. The global new energy automobile industry is gradually maturing through the coordinated development of the industrial chain, and an integrated model of the entire industrial chain might appear in the near future.

Disclosure statement

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