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Study on Green Development of BRI Automobile Industry

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Chapter I Introduction

1. Research Background

During his visit to Kazakhstan and Indonesia in September and October 2013, Chinese President Xi Jinping put forward the proposals of the Silk Road Economic Belt and the 21st-century Maritime Silk Road in succession, which became known as the Belt and Road Initiative (BRI). Since then, the BRI has received active response from a growing number of countries and international organizations [1], and aroused extensive attention from the international community, with influence being expanded with each passing day. As of January 2023, China had signed more than 200 documents for BRI cooperation with 151 countries and 32 international organizations.

Today, the green industry is blooming around the world. Many countries are stepping up policy support and investing in technology innovation to promote the transition and upgrade of economic structure, energy mix and the industrial sector , so as to realize the sustainable development of the economy and the society. According to an UNIDO report, in the past decade, faced with global resource shortage and environmental deterioration, countries have been launching strategies and policies related to green investment to support the development of the green industry. Focusing on sustainable development, green investment is of far-reaching significance to economic development. Many countries have taken actions to encourage green investment and promote green development. BRI participating countries are also making efforts to address environment and climate challenges and promote green and low-carbon transition of the economy.

The Belt and Road Initiative attaches equal importance to economic prosperity and green development. Promoting green development of the Belt and Road is an inherent requirement for practicing the concept of green development and promoting the building of an ecological civilization. It is a major measure to actively address climate change and safeguard global ecological security, and an important vehicle for boosting high-quality development of the Belt and Road and building a community of life for man and nature.

In March 2021, the *Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China* (abbreviated as the 14th Five-Year Plan) proposes that China will adhere to a vision of green development, openness and clean governance to promote high-quality development of the BRI, enhance cooperation in areas related to green development and promote the building of a green Silk Road. In March 2022, China National Development and Reform Commission, Ministry of Foreign Affairs, Ministry of

Ecology and Environment, and Ministry of Commerce jointly promulgated the *Opinions on Jointly Promoting Green Development of the Belt and Road*, proposing 15 tasks in 9 priority areas, including enhancing green transport cooperation. According to the document, China will consolidate international cooperation to help BRI participating countries to develop green transport, actively facilitate low-carbon development in the international shipping and aviation sectors, promote new energy and clean energy vehicle and vessels and other energy-saving and low-carbon transport, and share China's smart transport experience. The Report to the 20th National Congress of the Communist Party of China pointed out that the Belt and Road Initiative has been welcomed by the international community both as a public good and a cooperation platform and that we will promote the high-quality development of the Belt and Road Initiative.

To address climate change and fulfill the requirements of *The Paris Agreement*, countries around the world are announcing their carbon neutrality goals. As of April 2022, 131 countries had made carbon neutrality commitments. As a major contributor to carbon emissions, the transportation sector contributes to around 10% of China's total carbon emissions. Currently, countries around the world are taking actions to address climate change. Developed countries, in particular, are vigorously promoting the development of green and low-carbon transportation and have proposed the transition to a zero-carbon automobile industry. The automotive industry is an important pillar for economic development of both China and the world. In the face of increasingly severe challenges in environment, resource and energy, countries and industries are taking active measures to address climate change. Pursuing green and low-carbon transition has become the only option for the automobile industry if it wants to effectively address climate change and take sustainable development path. However, BRI participating countries adopted different administrative measures for environmental protection, pollution treatment, and resource & energy utilization. The automobile industry in these countries are in different stages of green transition. To ensure that the development of the automotive industry in BRI participating countries generate both economic and ecological benefits, we plan to carry out investigation of status quo of the green development of the automotive industry in regions along the Belt and Road.

According to the World Bank's standard for classification of national development level, BRI participating countries fall into four categories, namely, low income, lower middle income, upper middle income, and high income countries. BRI participating countries are in different stages of economic development. Most of them adopted an extensive development model, and started later in the transformation of resource & energy structure. Although faced with increasing

environmental damage as a result of the industrialization process, these countries fail to give enough attention to addressing climate change in the process of pursuing economic development, let alone implementing green development philosophies. As one of the important industrial sectors throughout the world, the automotive industry makes a major contribution to social & economic development and scientific & technological progress. In addition, closely related to the everyday life of the general public, the automobile industry also plays an important role in changing the way people behave. Moreover, the automotive industry can not only promote the development of numerous upstream industries such as steel, metallurgy, rubber, petrochemicals, glass, machinery, electronics, and textile, but also drive the development of downstream industries such as repair service, transportation, and insurance. Through adopting new technologies, new materials, new processes, and new equipment, the automobile industry has become an industry with considerable production and market scale that plays a major role in promoting national economic growth. However, the booming automobile industry also brings about environmental pollution and energy-related issues that needs to be addressed immediately. So, it is imperative for the automotive industry to bring down its negative impact on the environment and seek green, low-carbon, high-quality sustainable development.

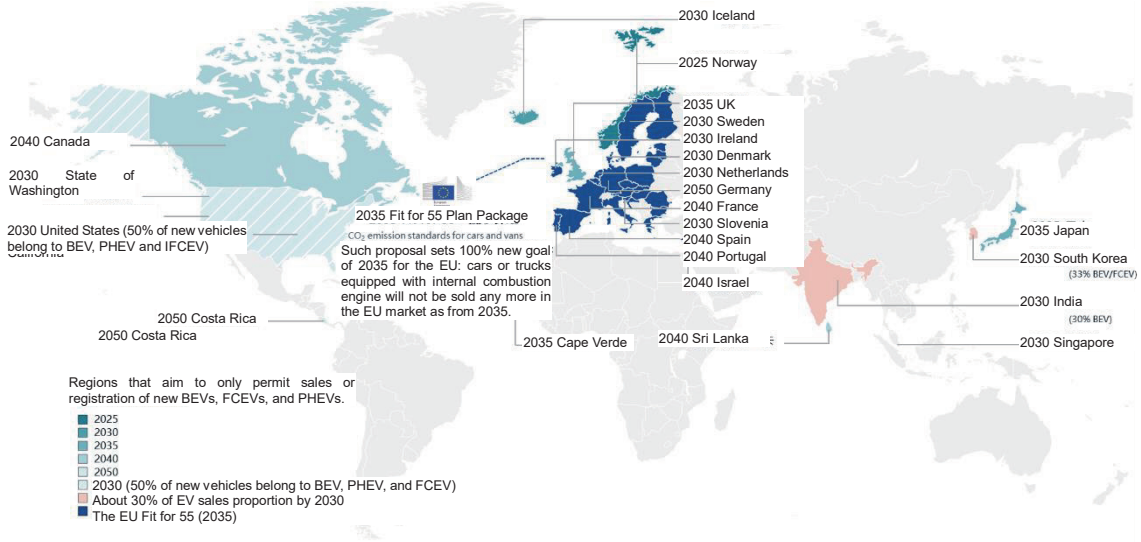


Fig. 1: Countries/regions that set the goal of phasing out sales or registration of new ICE automobiles[1]

[1] Data as of March 2022

So far, some countries and international organizations have issued green development strategies for the automotive industry, and begun to gradually confine the production and utilization of fuel vehicles (see Fig.1). For example, the EU, centering on the European Green Deal, put forward a series of policies and measures in eco-environmental conservation and governance, in which the EU Battery Management Regulations, Carbon Border Adjustment Mechanism(CBAM), Fuel Substitution Strategy, and Circular Economy 2.0, are relevant to the automotive industry. With more and more countries committing to transitioning the economy towards a new growth strategy, new policy barriers began to emerge. Countries and businesses that fail to take effective actions to promote green transition will be faced with greater pressure in the international arena, which will in turn, restrict the future development of their automobile industry.

currently, most BRI participating countries, without well-developed policy systems and effective actions taken by related enterprises, still have a long way to go before they realize green low-carbon and high-quality development. Since the 13th Five-Year Plan Period, China has been gradually promoting the green transition of the automobile industry. By now, the government has set up a relatively mature management system, and some businesses have realized green development from the perspective of the whole industrial chain, leading to a remarkable decline of carbon and pollutant emissions. With the international community pushing ahead with the green transition of the economy, as the initiator of the Belt and Road Initiative, China regards it as its responsible as a global major power to work together with other countries to jointly build the Belt and Road into a path towards green and low-carbon development.

2 Research Objectives

The report will review the development of the automotive industry in representative BRI participating countries through literature review, policy and statistics analysis, and analyze the progress, weaknesses and potential challenges of the green development of the automobile industry in BRI participating countries / regions from the perspective of regulatory requirements and real conditions. By referring to the advanced experience of relevant countries and regions (e.g., China and the EU) in industrial development, policy orientation, and green products, etc., the Report aims to help BRI participating countries to carry out green transition, improve the green competitiveness of automobile products, and promote the realization of both economic and ecological benefits in the automobile industry.

3. Scope of Research

Industrial scope: the Report mainly focuses on the green development of passenger cars and light commercial vehicles (LCVs), including the status quo of the development of the automobile industry; policies and management rules for the green development of the automobile industry; the consumption of energy-saving new energy vehicles.

Scope of countries and regions: three groups of countries are brought under study: Group I consists of only China; Group II consists of developing countries and regions with highly developed manufacturing industry and mature green development system, represented by the EU and the United States; Group III consists of six typical BRI participating countries (Singapore, South Africa, Portugal, Russia, Thailand and Indonesia) selected based on automobile production & sales scale, the development of standards, regional distribution, natural resource types, and data availability.

Research contents: 1. Basic information of the status quo of the automotive industry, for example, brand status, output and sales, new energy proportion, and NEV penetration rate, etc.; 2. Strategic planning and main policies for the green development of the automotive industry, for example, China Green Manufacturing Project, "30·60" Goals (Carbon Peaking and Carbon Neutrality Goals), oil consumption, and dual credits policy, etc.; 3. Measures and results in energy conservation renovation and green transition, etc. at the manufacturing end of the automotive industry; 4. Measures and results in the popularization of energy-saving products and new-energy products at the automobile consumption end.

4. Research Route

As the technical roadmap (see Fig.1) below shows, the report first analyzes the status quo and trend of green development in the three benchmark regions (China, the EU, and the United States), including basic information, top-level design, industrial development, and green consumption. The report then conducts a comparative study on BRI participating countries to find out the good practices and weakness of these countries, identify the opportunities and challenges of these countries in the green transition of the automotive industry, and propose recommendations for future development from three levels (country, industry, and enterprise).

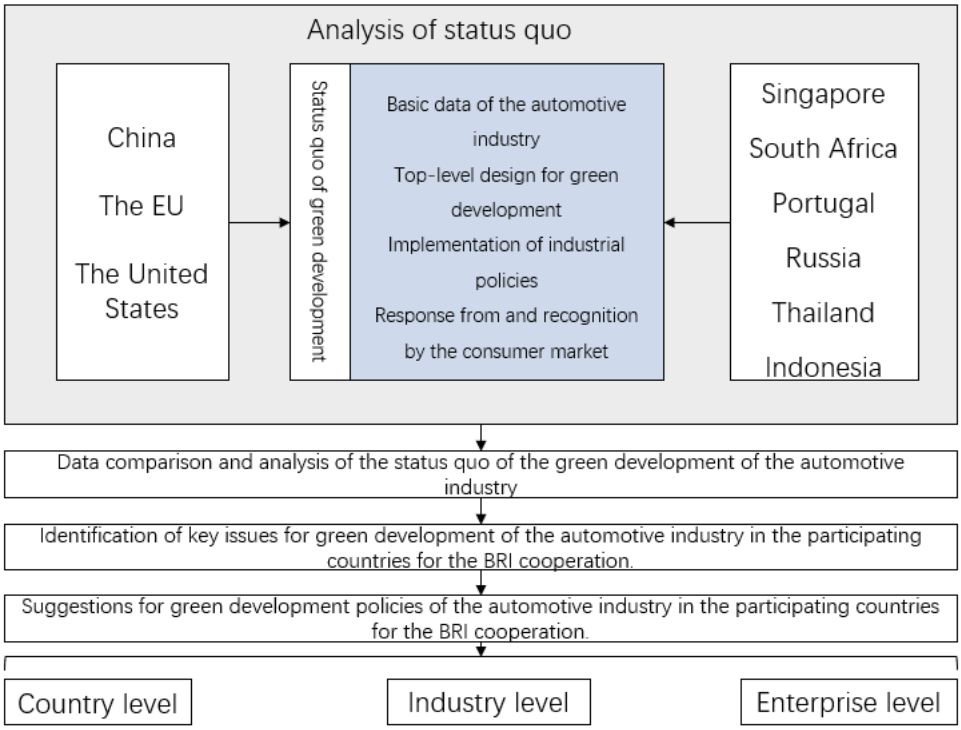


Fig. 2. Technical roadmap for research of status quo of the green development of the automotive industry in BRI participating countries

Chapter II Green Development of the Automotive Industry in China, the EU, and the United States

According to statistics in the report *The Automotive Industry in the Era of Sustainability* [2] released by France-based counseling agency Capgemini Research Institute, 62% of the automakers in the world have formulated all-around sustainable development strategy, and set clearly-defined goals and indicators[2]. However, enterprises and organizations are not moving at the same pace in the implementation of such strategies. It is estimated that an additional investment of US$ 50 billion is needed for automakers to fulfill their sustainable development commitments. In terms of electric vehicles (EV), 74% of OEMs have plans to manufacture EVs, whereas only 56% of them included electric vehicle in their sustainable development strategies. 52% of organizations in the industry have taken actions to support and promote the circular economy, but they are mostly still in the stage of issuing sustainable development initiatives. To give full play to the potential of sustainable development, they need to take further actions. Among sample automakers, only 9% of them have issued mature sustainable development plans, whereas 26% of them lagged behind. To realize green development, the automotive industry needs to take more practical and effective actions in policy incentive, organization management, and market guidance, etc.

1. Green Development of China Automotive Industry

(1) Overview of Industrial Development

Production and sales ranked first in the world. The automotive industry has become one of the major industries of China's national economy[2]. In 2021, the operating revenue of China's automotive manufacturing industry reached 8,670.62 billion yuan and the total profit reached 530.57 billion yuan, up 6.31% and 4.16% year-on-year respectively from 2020. In terms of auto's production and sales, China has been ranked first in the world for many years and maintained a high growth trend, and the annual increment of auto ownership has steadily increased to more than 20 million. By the end of 2021, the national automotive ownership, production and sales reached 302 million, 26.082 million and 26.275 million respectively, with a year-on-year growth

[2] https://www.capgemini.com/gb-en/news/automotive-sustainability-report/

of 7.5%, 3.4% and 3.8%[3] respectively[3] (see Fig.3).

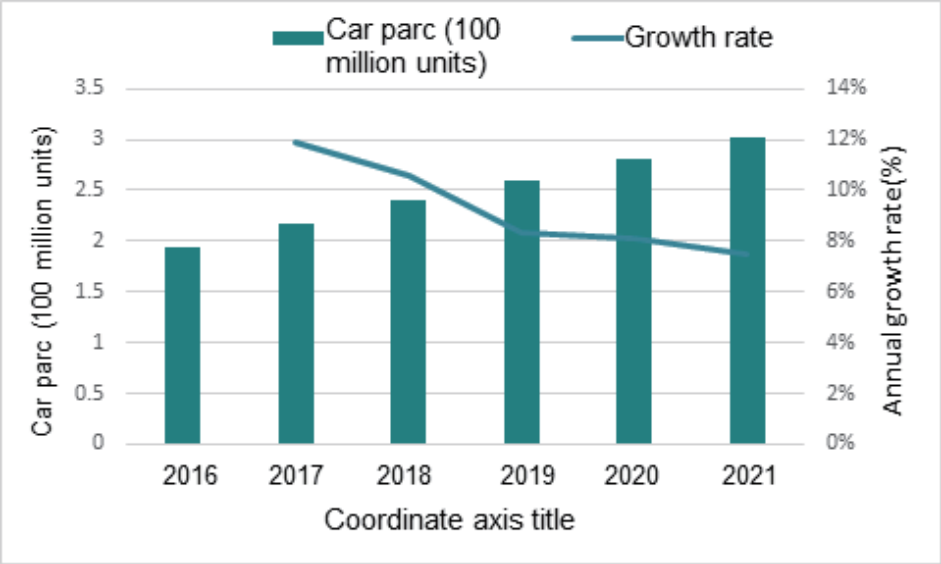


Fig. 3: China's Car Ownership and Growth Rate, 2016-2021

The NEV industry leads the world. In recent years, in the face of the global energy crisis and environmental pollution challenges, China has stepped up its efforts to explore environmental protection in the automotive sector and push the development of NEVs. Thanks to the vigorous promotion of national policies and continuous breakthroughs in core technologies, especially driven by the goal of "carbon peaking and carbon neutrality", China's NEV industry has developed rapidly, with the number of NEVs in China reaching 7.84 million and production reaching 3.545 million in 2021, up 59.34% and 159.52% respectively (see Fig.4). The output of new energy vehicles accounted for 13.59% of the country's total automobile output, and the retail penetration rate of NEVs reaches 14.8% in 2021, a significant increase from 5.8% in 2020. Along with the steady rebound of the national economy and the accelerated recovery of consumer demand, China's auto market still has ample room for development [4-5].

[3] Data source: *Summary of the Operation of China's Automotive Manufacturing Industry in 2021 and Forecast of Industry Trends in 2022* by China Business Industry Research Institute.

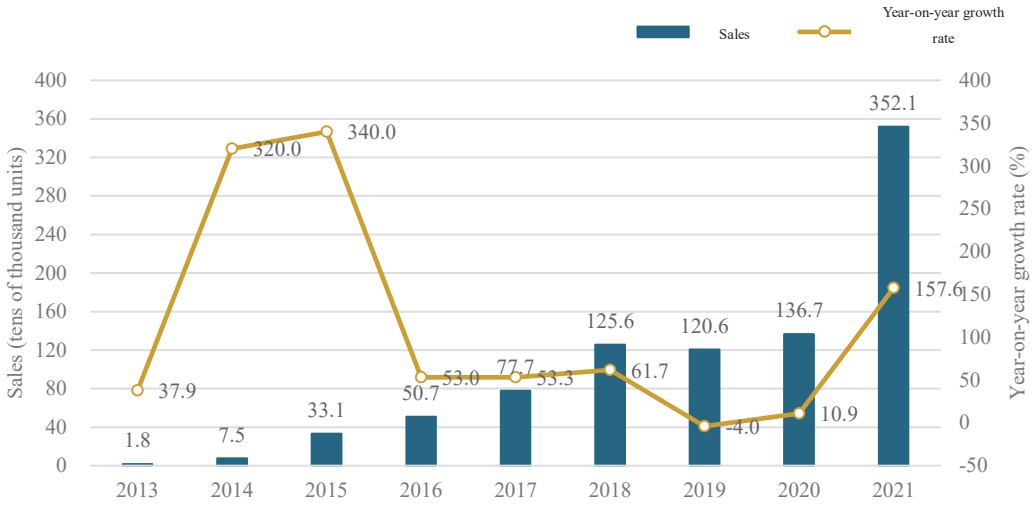


Fig. 4: China's NEV Sales and Growth Rate, 2013-2021

Auto products are entering the era of rapid "going out". China is also gradually transforming from a "big auto country" to a "strong auto country", and the growth trend of auto exports has further accelerated. In 2021, China's auto exports reaches a total of 2.015 million[4], 100% up year-on-year (see Fig.5), including 310,000 NEVs, a year-on-year increase of 3 times. Automotive products are becoming an important end product for both internal and external cycles of the Chinese economy[6] (see Fig.6).

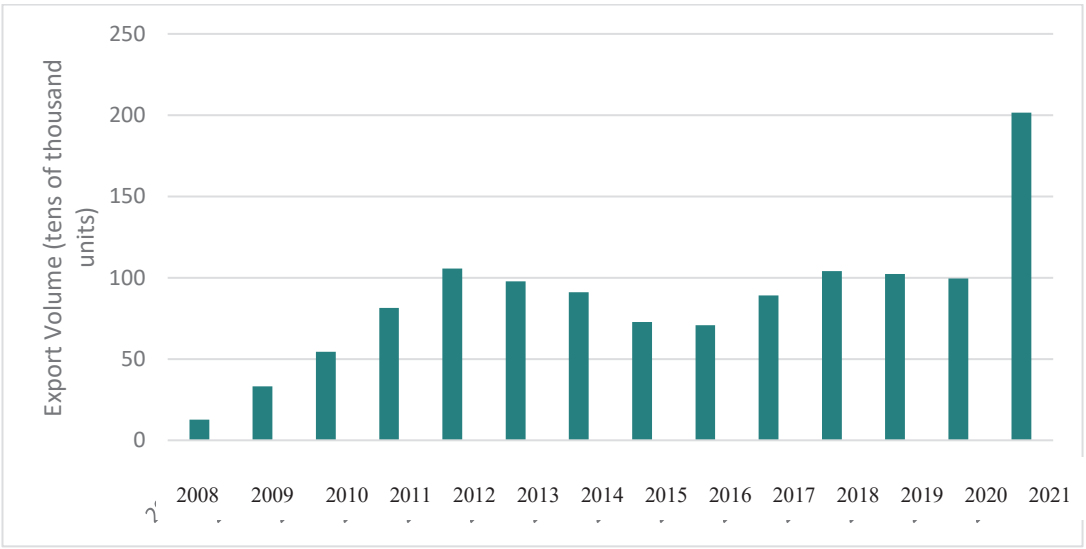


Fig. 5: China's Automotive Exports, 2008-2021

[4] Data source: Press Conference on the Development of the Automotive Industry in 2021, convened by MIIT

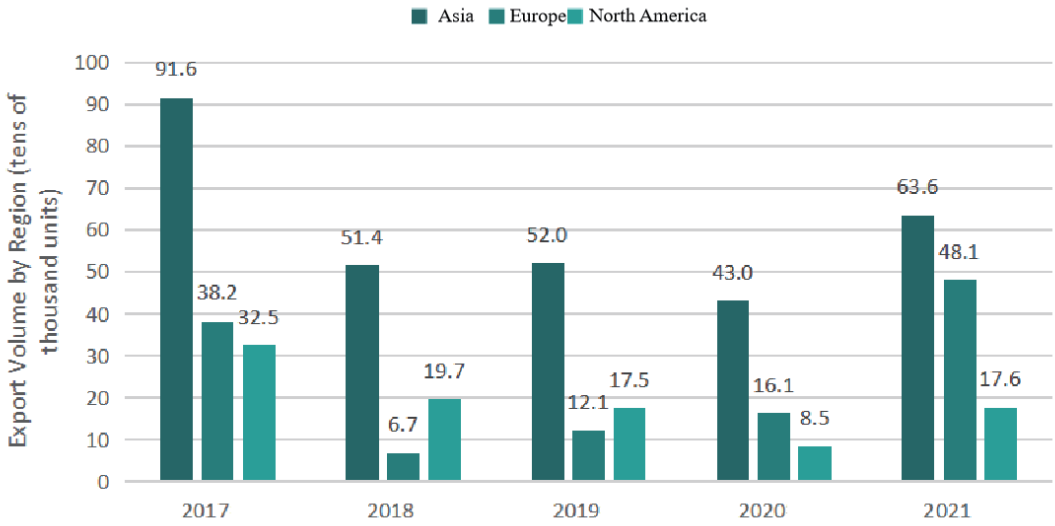


Fig. 6: Change of China's Automotive Export Destinations, 2017-2021

(2) Industrial Policy Design

During the 13th Five-Year Plan period, the concept of green development was written into the national five-year plan for the first time. During this period, China has gradually increased its efforts in pollution prevention and control, significantly enhanced the efficiency of resource utilization, and considerably improved the ecological environment. After entering a new stage of development, *the Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035* (the 14th Five-Year Plan) proposes to promote green development and facilitate the harmonious coexistence of people and nature. According to the Plan, by 2025, new gains in ecological civilization construction will be achieved and the ecological environment will continue to improve, and by 2035, the ecological environment will have fundamentally taken a turn for the better, and the goal of building a beautiful China will basically be achieved.

In September 2020, President Xi Jinping announced at the 75th General Debate of the United Nations General Assembly that China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures and we aim to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060. The automotive industry has become one of the key industries in China's carbon emission management because of its long industrial chain, wide radiation, fast growth of total carbon emissions and high carbon intensity per vehicle. Promoting the green and low-carbon transformation of the upstream and downstream chain of automotive industry is of great significance to achieve carbon neutrality in China.

In terms of top-level design, the top-level design of the green development of China's automotive industry is becoming more and more perfect, and the path of high-quality development of the industry is gradually clear. **Firstly, a working mechanism was perfected.** In November 2013, the State Council approved the establishment of the inter-ministerial joint conference system for the development of energy-saving and NEV industry (led by the Ministry of Industry and Information Technology (MIIT), with the participation of the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Finance and the Ministry of Public Security). Local governments have set up coordination mechanisms for industrial development, building a mechanism of horizontal synergy and vertical coherence for promoting the development of NEVs in China, which has played an important and positive role. **Secondly, a comprehensive policy system was established.** China's automotive industry has formulated a series of policies in the field of green energy conservation, implemented systematic standards, and local governments have introduced corresponding supporting policies in conjunction with the actual situation, covering six major areas of green product design, energy resource utilization, green supply chain construction, production and manufacturing emission reduction, green equipment manufacturing and renewable resource utilization, and promoted the green and low-carbon transformation of the entire industrial field, which has achieved positive results. Especially in 2020, the State Council issued *the New Energy Vehicle Industry Development Plan (2021-2035)*, which further clarified the direction of NEV development and greatly mobilized the enthusiasm of all sectors of society to support the development of NEV industry.

Since entering the new development stage, China has accelerated green and low-carbon transformation of auto industry: **first,** to clarify the roadmap for the implementation of the auto industry towards carbon peaking and carbon neutrality; **second**, to accelerate the formulation and implementation of carbon emission standards for the whole life cycle of automobiles, to clarify the boundary of carbon emission in the auto industry in the national carbon emission reduction program, and to specify the positioning, responsibility and target of carbon emission reduction in the auto industry; **third**, to further improve the policies that are conducive to the management and control of carbon emissions from automobiles, and form a low-carbon policy toolbox for the automotive industry; **fourth**, to promote the formation of synergy between the "Government-Industry-University-Research" parties, and accelerate the implementation of clean energy and green manufacturing technologies and the recycling of raw materials through technology incubation and project demonstration; **fifth**, to further increase the support for the use of NEVs,

for example, to continue to improve the construction of charging piles and other supporting facilities and provide preferential charging fees, to further foster an atmosphere that encourages the consumption of low-carbon products.

It can be seen that in the overall chain of industrial ecology, the core technology of China's auto industry continues to break through, industrial technology continues to innovate, and the development model is further optimized. The NEV industry ecology has evolved from a "chain relationship" among vehicles, parts R&D, production and marketing service enterprises to a "network ecology" with the participation of multiple entities in multiple fields such as automobiles, energy, transportation and information and communication. Green, low-carbon, high-quality development is also across the board, becoming a common topic of participation in the automotive industry upstream and downstream.

Promote the construction of green manufacturing system in depth. The automotive industry has been deeply implementing the requirements of *Made in China 2025* and *the Notice on the Construction of Green Manufacturing System*, vigorously building green factories, developing more than 10,000 kinds of green products and establishing green supply chains, and the green transformation of automotive enterprises has been effective. In terms of product design, the industry is actively carrying out green design demonstration pilot, in accordance with the concept of the whole life cycle, in the product design and development stage to systematically consider the selection of raw materials, production, sales, use, recycling, disposal and other aspects of the impact on resources and the environment, to achieve product consumption of energy and resources to minimize the ecological and environmental impact, and maximum renewable rate. At present, the automotive industry has 342 green factories (see Table 1 for a partial list), 162 certified green manufacturing products and 56 green supply chain units. Among the 6th batches of green manufacturing system construction lists from the MIIT, automotive and component companies have successfully declared 162 green design products, including 56 whole vehicle products[7].

Table 1: Factories Related to the Automotive Industry in MIIT's 5th Batch of Green Plants (Partial)

Number	Region	Plant Name
1	Beijing	Beijing BAI Lear Automotive Systems Co., Ltd
2	Tianjin	Tianjin FAW Toyota Motor Co., Ltd.
3	Tianjin	Tianjin Branch of FAW Volkswagen Automotive Co., Ltd.
4	Tianjin	Tianjin Lingyun High-tech Automotive Technology Co., Ltd.

5	Jilin	Changchun Antolin Automotive Interiors Co., Ltd.
6	Jilin	Changchun Minth Automotive Parts Co., Ltd.
7	Jilin	Changchun Changchun Automotive Interior Parts Co., Ltd.
8	Jilin	Faw Jiefang Automotive Co., Ltd.
9	Shanghai	Shanghai Volkswagen Automotive Co., Ltd.
10	Shanghai	SAIC General Motors Corp. Ltd.
11	Jiangsu	Jiangsu Changshu Automotive Trim Group Co., Ltd.
12	Anhui	Anhui Hualing Automotive Co., Ltd.
13	Anhui	Chery Automotive Co., Ltd.
14	Hubei	Dongfeng Honda Automotive Co., Ltd.
15	Hubei	Car Manufacturing Factory of Dongfeng Commercial Vehicle Co., Ltd.
16	Hunan	Changsha Branch of Shanghai Volkswagen Automotive Co., Ltd.
17	Hunan	Bosch Automotive Products (Changsha) Co., Ltd.
18	Hunan	GAC Mitsubishi Automotive Co., Ltd.
19	Guangxi	Passenger Car Base of Dongfeng Liuzhou Motor Co., Ltd.
20	Sichuan	Chengdu Branch of FAW Volkswagen Co., Ltd.
21	Ningbo	Ningbo Hangzhou Bay Plant of Zhejiang Geely Automotive Co., Ltd.
22	Qingdao	Qingdao Branch of FAW-Volkswagen Automotive Co., Ltd.
23	Shenzhen	Shenzhen Baoneng Motor Co., Ltd.

Guide automotive enterprises to implement cleaner production. Most automotive manufacturing enterprises have achieved significant results in reducing emissions, and breakthroughs in environmental protection processes. For example, Longfin Nissan Huahuadu Plant invested more than 45 million yuan to improve three waste treatment facilities, the normal operation rate of environmental protection facilities reaching 100%, with 100% of the treated water meeting the water reuse standards. In addition, waste treatment and disposal rate reached 100%, including a comprehensive utilization rate of 93%. The comprehensive utilization rate of industrial waste of Guangzhou Honda reaches 90%, and the disposal rate of hazardous waste reaches 100%. The factory does not have any external outfall, and through sewage treatment, 100% of the sewage is recycled and reused, realizing "zero discharge" of sewage.

Improve the guidance system for comprehensive utilization of resources. China has issued documents or standards including the *Administrative Measures for the Recovery of Scrapped Motor Vehicles*, *Detailed Rules for the Implementation of Administrative Measures for the Recovery of Scrapped Motor Vehicles*, *Technical Specifications for End-of-life Vehicles Collecting and Dismantling Enterprises*, and *Environmental Protection Technical Specifications for*

Disassembly of End-of-Life Vehicles and the development of domestic motor vehicle recycling and dismantling has been gradually standardized. At the same time, with the rapid rise in the ownership of NEVs, the recycling and gradient utilization of power battery materials has received more and more attention. According to the data of China Automotive Technology Research Center (CATARC), the cumulative amount of power battery retired in China is about 200,000 tons in 2020 and will be 780,000 tons in 2025. According to the 14th Five-Year Plan, China's power battery recycling will be managed from various aspects such as construction of traceability management platform, traceability management of product recycling, standardized gradient utilization, and technology level improvement to solve the unfair competition, difficulties in collecting retired power batteries, gradient utilization, and safety deficiency of battery recycling technology that exist in the industry. In the face of the huge number of retired batteries in the future, improving the power battery recycling system is still an important task for China's auto industry.

Table 2: Policies Related to Green Development of China Automotive Industry

Sectors	Policies	Date of Issuance	Contents
Industry	*Industrial Green Development Plan(*2016-2020)	2016.7	Main objectives for industrial development
Carbon Emission	*Action Plan for Carbon Dioxide Peaking Before 2030*	2021.10	Bring forth concrete action path for low-carbon development
	GB 27999-2019 *Fuel Consumption Evaluation Methods and Targets for Passenger Cars* (GB 27999—2019)	2019.12	Assess the enterprises' average fuel consumption
	GB 19578-2021 *Fuel Consumption Limits for Passenger Cars (*GB 19578—2021)	2021.7	Conduct limit management over single car model's fuel consumption
Green Design	*Guidance on the Development of Eco-Design of Industrial Products*	2013.2	List ecological design of automotive products as the priority
	Requirements for Managing Hazardous Substances and Recyclability of Vehicles	2016.1	Manage utilization and recoverability rate of M1 passenger vehicle's hazardous substances
	GB 27630-2011 *Guideline for Air Quality Assessment of Passenger Car (*GB 27630—2011)	2017.1	Enforce mandatory standard management over in-car air
	GB/T 30512-2014 *Requirements for Prohibited Substances on Automobiles (*GB/T 30512—2014)	2014.2	Prohibit use of mercury, cadmium, hexavalent chromium, and PBBs
	GB/T 19515-2015 *Road Vehicles-Recyclability and Recoverability-Calculation Method (*GB/T 19515—2015)	2015.12	Calculation method and scope for vehicle recyclability rate and recoverability rate
	GB/T 39897-2021 *Determination of Volatile Organic Compounds and Aldehydes and Ketones in Nonmetallic Parts of Vehicles (*GB/T 39897—2021)	2021.3	Formulate standards related to in-car parts
Green Supply Chain	GB/T 24040-2008 *Environmental Management-Life Cycle Assessment-Principles and Frameworks (*GB/T 24040—2008)	2008.5	General standard for life cycle assessment
	Evaluation Requirements of Green Supply Chain Management	2016.9	Coordination between corporate economic activities and environmental protection
	*Green Manufacturing-Manufacturing Enterprise Green Supply Chain Management (*GB/T 33635—2017)	2020.9	Comprising guide, informatized platform management, evaluation specification, procurement control, and five standards for material list requirements
Green Factory	*Law of the People's Republic of China on the Promotion of Clean Production*	2012.2	Make laws for the economic and social sustainable development
	GB/T 36132-2018 *General Principles for Assessment of Green Factory (*GB/T 36132—2018)	2018.5	Clarify terminology definition, establish assessment system, and put forward assessment requirements
	Plan for Comprehensive Treatment of VOCs in Key Industries	2019.6	Formulate standard, clarify task, and improve system
Green Product	*Measure for Dual-Credit Management of Passenger Car Enterprises' Average Fuel Consumption and New-energy*	2017.9	Establish dual credits mechanism, and promote the industry's energy conservation & emission reduction and

	Vehicles		transformation & upgrading.
	GB 18352.6-2016 *Limits and Measurement Methods for Emissions from Light-duty Vehicles (CHINA 6)* (GB 18352.6—2016)	2016.12	Conduct overall management to automotive pollutants
	Notice on Further Perfecting Fiscal Subsidy Policy for Popularization and Application of New-energy Vehicles	2020.12	Keep carrying out new-energy subsidy policy, support the industry's high-quality development, and do a good job of NEV popularization and application
	the New Energy Vehicle Industry Development Plan (2021-2035)	2020.11	Promote the new-energy industry's high-quality development
Green Recovery	*Administrative Measures for Scrap Motor Vehicle Recycling (Amendment)*	2019.5	Specify recovery of scrap motor vehicles, protect environment, and promote development of circular economy
	GB 22128-2019 *Technical Specifications for End-of-life Vehicles Collecting and Dismantling Enterprises* (GB 22128—2019)	2019.12	Specify recovery and dismantling enterprises' address, facility construction, dismantling technology, environmental protection, and NEV dismantling
	Interim Measures for the Administration of the Recycling of New Energy Vehicle Traction Batteries	2018.2	Specify the administrative measures in traction battery design & production, recovery responsibility, comprehensive utilization, and monitoring management
	Measures for the Administration of the Cascade Utilization of Traction Batteries for New Energy Vehicles	2021.8	Take advantage of existing recovery channel to efficiently collect disused traction batteries for cascade utilization
Green Finance	*Guide for Issuance of Green Bonds*	2015.12	Delimit the scope of projects supported by green corporate bond and the concessional terms for issuance
	Guiding Opinions on Building a Green Financial System	2016.8	Delimit connotation, bring forth measures, and stress information disclosure
	Guiding Opinions on Accelerating the Establishment and Improvement of a Green, Low-carbon and Circular Economic Development System	2021.2	Foster green trading market mechanism, and further improve the trading mechanism such as carbon emissions trading
	Green Finance Evaluation Scheme for Financial Institutions in the Banking Industry	2021.6	Clarify the roster of banks included in green finance evaluation scheme, and determine quantitative and qualitative green finance evaluation indicators

(3) Green Consumption of Products

From the perspective of time, the promotion of energy-saving and new energy products in China falls into three stages of development. The first stage is from 2009 to 2015, when green vehicle products are in the industrialization and development period, and the relevant subsidy policies promote the rapid development of the new energy industry and lay the foundation for the market development of new energy products. In 2016-2021, the market dominated by new energy products has gone through the introduction period, the growth period and entered a period of rapid growth, from "policy-driven" to "market-driven" gradually. From 2022, the relevant products will enter the maturity period, and the annual sales of new energy vehicles reached 5 million in 2022.

Product energy saving and carbon reduction is effective. Regarding energy consumption, under the joint promotion of supply-side reform and green development policies, energy consumption and carbon emissions of automotive products have dropped significantly compared with previous years, with remarkable results in energy saving and emission reduction. In order to promote the development of NEV industry and urge enterprises to reduce fuel consumption, China officially launched the double-credit policy in 2016. The double-credit policy takes into account both the fuel consumption and NEVs credit system, leading enterprises to focus on energy saving and emission reduction. According to *the Announcement of Chinese Passenger Car Enterprises' Average Fuel Consumption and NEV Credits in 2021* newly issued by MIIT, in 2021, 129 passenger vehicle enterprises in China produced/imported passenger vehicles with an average overall vehicle mass of 1,533 kg and an average fuel consumption of 5.1 liters/100 km (see Fig.7) in real terms (WLTC conditions). The positive fuel consumption credits were 15,939,900, the positive fuel consumption credits 15,939,900, the negative fuel consumption credits 5,632,500, the positive credits for NEVs 6,790,000, and the negative credits for NEVs 797,900, which effectively promoted the transformation of China's auto industry to energy-saving and low-carbon direction.[5] The results brought by the fuel consumption control policy are obvious, but the values of single-vehicle energy consumption and full life-cycle CO2 emissions are still far from the international top level.

[5] Dual Credits: CAFC (Corporate Average Fuel Consumption) credit and NEV (New Energy Vehicle) credit, or called oil consumption credit and new energy credit for short. Requirement: automakers' annual dual credits must be positive.

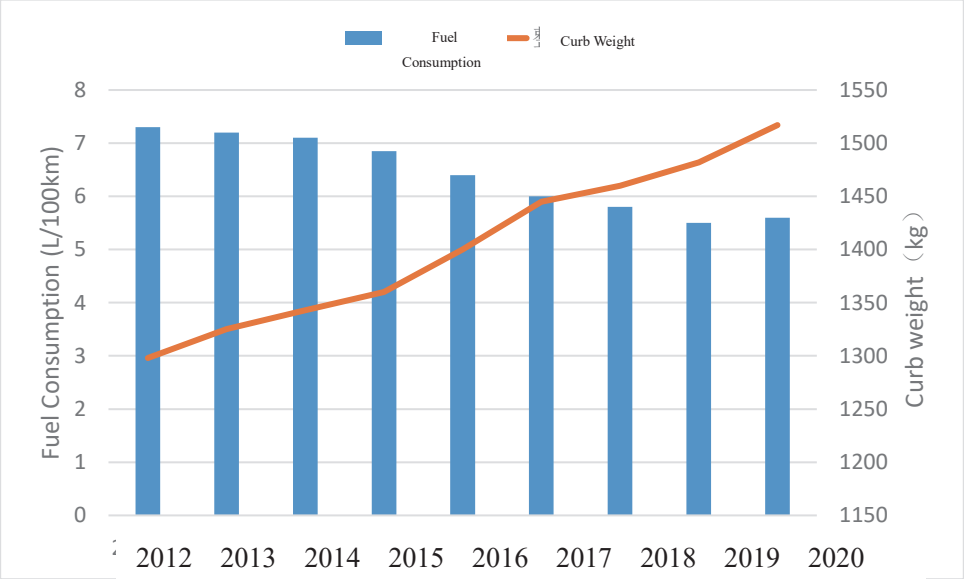


Fig. 7: Change of Chinese passenger car's average fuel consumption and curb weight, 2012-2020

NEV consumption support continues. In order to increase the application of energy-saving and emission reduction technologies and the popularization of NEVs, China has implemented a series of stimulating policies in the acquisition and use of vehicles on the consumption side. During the acquisition, policies including subsidies for NEVs acquisition, exemption from vehicle purchase tax for new energy vehicles and a 50% reduction in vehicle purchase tax for passenger vehicles with a displacement of 1.6 liters and below, as well as vehicle purchase quota indicators in favor of NEVs have been implemented. In June 2022, the Ministry of Ecology and Environment, the National Development and Reform Commission and seven other departments jointly issued *the Implementation Plan for Synergizing the Reduction of Pollution and Carbon Emissions*, proposing to "accelerate the development of new energy vehicles ..... by 2030, in the key regions of air pollution prevention and control, new energy vehicle sales shall account for about 50% of new vehicle sales."

Increase the establishment of new energy infrastructure. As an important guarantee and prerequisite for the promotion of NEVs, by the end of 2021, the national charging infrastructure was 2.62 million units, which is still slightly weak in front of the rapidly rising fleet size, and there is a more obvious problem of uneven distribution. With the rapid development of the NEV industry, the current infrastructure construction still needs to be stepped up. To this end, in 2022, the NDRC specifically issued *the Implementation Opinions on Further Improving the Service Guarantee Capability of Electric Vehicle Charging Infrastructure*, requiring that by the end of the

14th Five-Year Plan, China's electric vehicle charging guarantee capability will be further improved, forming a charging infrastructure system that is moderately advanced, balanced in layout, intelligent and efficient, in order to meet the charging needs of more than 20 million electric vehicles.

The level of ecological design of automobiles has been significantly improved. With the transformation and upgrading requirements of the industry development, in order to enhance the green and low-carbon development of the automotive industry and guide green consumption, the Chinese government attaches great importance to product eco-design, and has released *the Plan for Industrial Transformation and Upgrading (2011-2015)*, *Industrial Green Development Plan (2016-2020)*, *Guide for Implementation of Green Manufacturing Project (2016-2020)*, *Notice on Implementing Green Manufacturing System Construction* and other documents, put forward the creation of green products, and prioritized the automotive and other industries to organize pilot demonstrations. In order to increase the market supply of green ecological products and guide the industry to improve ecological design, the Chinese government has also issued documents such as *Opinions of the General Office of the State Council on Developing a Unified Standard, Certification and Identification System of Green Products*, which promotes a voluntary product certification system and encourages third-party industry organizations to evaluate or certify the ecological performance of products. Since 2012, the relevant departments have commissioned CATARC to conduct researches on the ecological design system of automobiles, and successfully created the brand of "China Eco-Car". The overall content research and index setting of the project has reached international advanced and the research results have been widely used in the automotive industry and have been highly recognized by more than 40 mainstream passenger car enterprises at home and abroad, effectively promoting the technological progress of the industry, and forming a mature Eco-car positive R&D system in the selection of environmental-friendly materials, performance tuning of noise, vibration and harshness (NVH), application of advanced energy-saving technologies, harmful substance reduction technologies and low-carbon production processes of automobiles.

China Eco-car certification is a comprehensive assessment of automotive products health, low-carbon, environmental protection and other performance indicators, which mainly contains three aspects. First, "health", that is, to improve the air quality, reduce noise and electromagnetic radiation in the car, reduce the use of harmful substances and to ensure the health of the driver and the rider. Second, "low-carbon", that is, to reduce carbon emissions throughout the life cycle

of the model and practice a low-carbon lifestyle. Third, "environmental protection", that is, to reduce tailpipe emissions, to achieve the source of environmental pollution management. For the specific index system, see Annex 1. Since its official implementation in 2015, Eco-car has released a total of 14 batches of 56 models evaluation results.

Overall, after the rapid development stage of China's auto industry, green and low-carbon transformation has become an important topic at this stage of development. Achieving low-carbon transformation is a huge systematic project, and it is also a necessary path for China's auto industry to achieve high-quality and sustainable development. Chinese automobiles have initially created core capabilities and competitive advantages in low-carbon production, technology, products and other aspects, and the initial results of green development of automobiles have been reflected.

2. Green Development of the EU's Automotive Industry

(1) Overview of Industrial Development

Data from European Automobile Manufacturers Association (ACEA) reveal that in 2020, sales of new cars in Europe totaled 11.96 million units, of which, sales of new-energy passenger cars exceeded 1.36 million units, up by 142% YoY and accounting for 11% of the entire European automobile market. Judging from this we can see that NEV has become a major component of the EU automotive industry. In addition, the EU is tightening its control over carbon emissions. According to the EU's "Fit for 55"[8] Package issued in July 2021 and the Amendment to raise the energy-saving targets approved in July 2022, the EU will make proportion of renewable energy hit 45% by 2030. Regarding relevant schemes, the EU has brought forth more specific requirements in the fields of green hydrogen, transportation, and construction, etc. For example, the carbon emission reduction goal for cars rose from the original 37.5% to 55%; the one for trucks rose from 31% to 40%. Moreover, the EU pledged to reducing CO_2 emission from new vehicles to zero by 2035, which means an end to the use of gasoline and diesel engine. According to estimates, under the guidance of new policies, sales of NEVs in European market will hit 11.13 million units by 2030, reaching a penetration rate of 65.1%[9]. Under the influence of these measures, European automakers have successively made public their own green development and electrified transition goals (see Fig.3).

Table 3: Green development and electrification transformation goal of Some European automobile enterprises

Logo	Name of automobile enterprises	Green development and electrification transition goals
	BMW	By 2030, it aims at making the average carbon dioxide emission per car in life cycle decrease at least by one-third from 2019.
BOSCH	BOSCH	In 2020, it has realized "Carbon Neutrality" in 400-odd business places across the globe, and become the world's first large-scale industrial enterprise that realized the "Carbon Neutrality" goal. By 2030, it aims at bringing down carbon dioxide emissions by 15% (from that in 2018) in the entire value chain from suppliers to customers, and cutting down the carbon emissions by 67 million tons in total.
DAIMLER	DAIMLER	By 2039, it aims at making all passenger cars under DAIMLER meet the goal of "Carbon Neutrality".
VOLVO	Volvo	It is committed to building the company into a global climate zero-load benchmark enterprise by 2040.
RENAULT	RENAULT	It plans to realize "Carbon Neutrality" by 2050.
Volkswagen	Volkswagen	It plans to realize "Carbon Neutrality" by 2050.

(2) Industrial Policies

So far, the EU has been following the principle of green development for over three decades. It's been leading in the world on aspects of goal setting and top-level framework design, and has built a comprehensive regulatory system[9].

As early as 2005, the EU rolled out Emissions Trading System (EU-ETS), making it the world most full-fledged emissions trading market with the largest number of participating countries. In 2007, the EU launched the "20-20-20" plan for 2020, according to which, by 2020, the EU would improve the energy efficiency by 20%, bring down the carbon dioxide emission by 20%, and make the proportion of new energy hit 20% as compared to that in 1990. In 2011, the EU launched the *Energy Roadmap 2050*, *2050 Roadmap to Low-carbon Economy*, and *Reducing Greenhouse Gases: a Roadmap for 2050*,,promising that by 2050, it will reduce GHG emissions by 80%-95%, relative to that in 1990. In December 2019, the EU enacted the European Green Deal, announcing that it will live up to carbon neutrality in Europe by 2050. To achieve this goal, Europe promised

to reduce the carbon emissions by 55% by 2030, and adopt policy (including establishing a carbon emission trading system, promoting renewable energy, and improving carbon dioxide emission standard for cars and trucks, etc.) in the 2021“Fit for 55 Package”.

As a pillar industry and high-polluting industry, the automotive industry has always been a key node for energy conservation & emission reduction and green development. Since sustainable development was put on agenda by the European Commission in 1990s, relevant policies and standards have been enacted and refined successively. So far, the policy system for the automotive industry has become a major component of the EU’s legal system of environment and climate change, and it covers different sub-fields under the environmental system, including air pollution, noise, industrial pollution, environmental control, and environment conventions, with relevant policies enacted for different stages of the life cycle. The policies related to the green development of the European automobile industry are shown in Table 4

Table 4: Policies for the green development of European automotive industry

Field	Number	Title	Key contents and objectives
Top-level scheme	COM(2021) 550	Fit for 55	It promises to bring down GHG emissions by 55% by the end of 2030, relative to that in 1990
	COM(2011)112	*Roadmap for a low carbon economy by 2050*	A series of roadmaps stipulating that by 2050, the EU will bring down its GHG emissions by 80%~95%, relative to that in 1990.
	2018/842/EU	Regulation on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030	To promote climate action, and fulfill the *Paris Agreement*
	2003/87/EC	Directive on establishing a scheme for greenhouse gas emission allowance trading within the Community	To Establish the EU's Emissions Trading System (EU-ETS)
	2016/2284/EU	Directive on the Reduction of National Emissions of Certain Atmospheric Pollutants	To reduce risk and influence of air pollution on health by making national emission reduction promise.
Green design	2014/540/EU	Regulation on the sound level of motor vehicles and of replacement silencing systems	To improve the environment by reducing noise sources caused by motor vehicles
	2018/858/EU	Regulation on the Approval and Market Surveillance of Motor Vehicles and Their Trailers, and of Systems, Components and Separate Technical Units Intended for Such Vehicles	Unified rule for emission types in Euro V and Euro VI standards and test certification method
	2006/40/EC	Directive relating to emissions from air-conditioning systems in motor vehicles	To specify the air conditioning system emissions, and phase out products of GWP>150
	2019/631/EU	Regulation Setting CO_2 Emission Performance Standard for New Passenger Cars and for New Light Commercial Vehicles	To reduce passenger cars' average annual carbon dioxide emissions fall by 15% during 2025-2029 relative to that in 2021, , and new cars' carbon dioxide emissions in 2030 fall by 37.5%
	2009/125/EC	Directive on Establishing a Framework for the Setting of Eco-design Requirements for Energy-related Products	To perform ecological design to existing industrial products to alleviate the environmental impact, and realize energy conservation through better design.
Green product	1999/94/EC	Directive relating to the availability of consumer information on fuel economy and CO2 emissions in respect of the marketing of new passenger cars	Information must be displayed on automotive labels, posters, and other publicity materials or in specific guides, in order to assist consumers in making choice
	2009/33/EC	Directive on the Promotion of Clean Road Transport Vehicles in Support of Low-emission mobility	To promote and stimulate the development of clean/energy-saving vehicle market
	2018/2001/EU	Directive on the promotion of the Use of Energy from Renewable Resources	To establish the general framework to promote development of renewable energy, limit GHG emissions, and set goals for use of renewable energy in 2030
Green supply	2014/94/EU	Directive on the Deployment of Alternative Fuels	To promote the construction of hydrogen fueling station and the

chain		Infrastructure	infrastructure for clean fuels such as CNG and LNG.
	2009/126/EC	Directive on Stage II petrol vapor recovery during refueling of motor vehicles at service stations	To take actions to deal with gasoline storage and distribution, in order to reduce VOCs in the atmosphere
	2003/96/EC	Directive on restructuring the Community framework for the taxation of energy products and electricity	To institute the EU's tax provisions on electric power, all automotive fuels, and most heating fuels, and ensure stable operation of the EU's single-energy market.
Green recovery	2005/64/EC	Directive on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability	To promote reusability, recoverability, and recyclability of motor vehicles, and minimize the hazard to environment
	2008/98/EC	Directive on Waste	To mitigate negative impact of waste generation and management on the human health and environment, reduce use of resources, and promote the actual application of waste grading system
	2000/53/EC	End-of-Life Vehicle(ELV) Directive	To mitigate the impact of end-of-life vehicles on the environment, in order to protect, maintain and improve the environmental quality, and to save energy
	2020/353/EU	Regulation on imposing a definitive anti-dumping duty and definitively collecting the provisional duty imposed on imports of steel road wheels originating in the People's Republic of China	To ensure that batteries launched in the EU market are sustainable and safe in the life cycle, and minimize the negative impact of cells, batteries, and waste batteries.

For product green design, regulations and directives enacted by the EU cover pollutant emission, GHG emission, certification, vehicle noise and sound elimination system. To be precise, *Regulation on Approval and Market Surveillance of Motor Vehicles and Their Trailers, and of Systems, Components and Separate Technical Units Intended for Such Vehicles* (2018/858/EU), which provides unified rules and testing methods that meet Euro V and Euro VI standards, is the world's most stringent and advanced rule, and provides experience and references for drafting relevant emission standards in other countries. Regulation on Setting CO_2 *Emission Performance Standards for New Passenger Cars and for LCVs* (2019/631/EU) provides the 2030 vision and roadmap for the vehicles' GHG emissions, stipulating that relative to that in 2021, new cars' average annual carbon dioxide emissions should drop by 15% during 2025-2029, and fall by 37.5% in 2030. In addition, the EU has put forward provisions and limitations over energy-related green design products, in order to better improve the production capacity and resource efficiency. Moreover, the EU set limitations on vehicle air conditioning system's emissions and vehicle noise. For products, the EU emphasized on the promotion of renewable energy, and established a general framework for promoting renewable energy in the *Directive on the Promotion of the Use of Energy from Renewable Resources* (2009) (2018/2001/EU), in order to limit GHG emissions. In addition to setting the goal of 2020, the EU pointed out that renewable energy efficiency of the transportation industry would reach 10% by 2030, and brought forth higher requirement (14%) in the Revision issued in 2018. Under the overall energy deployment, the EU promulgated the *Directive on the Promotion of Clean and Energy-efficient Road Transport Vehicles* (2009/33/EC) to popularize NEVs and other clean vehicles, in addition to strongly popularizing NEVs including electric vehicles and natural gas vehicles, in order to improve the transportation industry's contribution to EU's environment, climate, and energy reform. When the product is launched onto the market, the EU requires compulsory disclosure of fuel economy and GHG emissions, in order to give reference to consumers in purchase.

For the supply chain that links raw materials, products, and consumers, the EU strongly promotes the construction of NEV infrastructure, such as hydrogen fueling station, and infrastructure for clean fuels including CNG and LNG, etc. Regarding traditional energy, the EU limits their storage methods and distribution procedure as a way to reduce volatilization of hazardous substances in the air. For the foremost end of the industrial chain, the EU limits the power product system, sets different taxation rules for different industrial categories and fuel types, in order to improve the NEV's competitiveness and popularize NEV products.

At the recovery end, the EU has been implementing the *End-of-Life Vehicle(ELV) Directive* (2000/53/EC) for nearly 20 years, which, after being revised for multiple times, has become an outline document in the motor vehicle scrapping and recovery field. Under the joint guidance of this directive and the EU's *Waste Framework Directive*, the EU kept refining its policy and law systems at the recovery end, for example, the EU has enacted the recyclability, reusability, and recoverability policy, and battery and waste battery regulation in succession, executing mandatory requirements over recovery of automobiles, particularly NEVs.

(3) Green Consumption of Products

In 2022, the EU countries reached an agreement on the Renewable Energy (Electricity) Amendment (Percentages) Regulations and they all supported the goal of realizing vehicles' zero-carbon emission by 2035, implying that they will not sell fuel vehicles any more at that time, and they will assess the hybrid vehicle's conformity to this goal in 2026.

Europe's policy measures that boost the development of NEVs also include multiple positive incentive policies. On one hand, European countries keep increasing fiscal subsidies to electric vehicles (see Table 5), for example, Germany released the Environmental Award respectively in February 2020 and in June 2020, increasing subsidy per car for battery electric vehicle (BEV) from 4,000 euros to 6,000 euros and then to 9,000 euros; Netherlands began to give subsidy of 4,000 euros to electric vehicle priced at below 45,000 euros as from July 2020; France released the *EUR 8 Billion of Automotive Industry Revival Plan* in May 2020, and it increased the subsidy from 6,000 euros to 7,000 euros to household light-duty vehicle with carbon emission of below 20g/km and sales price of below 45,000 euros .

Table 5: European New-energy Subsidy Policies

Country/Region	New energy subsidy policy	VAT	Time for Sales Prohibition of Fuel Vehicles
The EU	Setting up 40-60 billion euros of clean vehicle investment fund to speed up investment in zero-emission power system	Exemption of VAT on zero-emission vehicles	-
Norway	Its preferential policy for BEV will be prolonged till 2025	Exemption of purchase tax, import duties, and VAT on BEV	2025
The UK	Electric vehicle purchase subsidy is prolonged till 2023, and new energy subsidy scope is strictly delimited.	Exemption of purchase tax on NEVs	2030
France	Discount of 6,000 euros is provided to electric vehicle and oil-electric hybrid vehicle with	20%	2040

	displacement of below 20g/km		
Italy	3,500 euros of subsidy is provided in replacement of old car with low-emission new car; new car purchase subsidy is up to 8,000 euros	22%	2035

In terms of infrastructure construction, according to the Proposal Package for Addressing Climate Change issued by the EU in 2021, EU countries would build a charging station every 60 kilometers, and a hydrogen fueling station every 150 kilometers on main expressways by 2035. However, relevant supporting infrastructure for electric vehicles in Europe is still in short supply, which hinders further expansion of the market. ACEA noted that European countries need to continue increasing their investment in electric vehicle infrastructure. Calculation results show that to meet future users' needs, up to 14,000 public charging piles need to be installed every week within the administrative scope of the EU, but only less than 2,000 charging piles are installed in the EU every week at present.

The EU is one of the first regions that practice sustainable development notion, and now, it boasts complete laws & regulations and implementation foundation. In addition, member countries and large-scale automakers have been fully prepared and are equipped with relatively sound foundation for the green industry. However, affected by its existing energy's external dependence and volatility of the international situation, the EU automotive industry is still faced with uncertainties though its green development process runs well.

3. Green Development of the Automotive Industry in the United States

(1) Overview of Industrial Development

Data from Cox Automotive reveal that in 2020, car sales in the United States amounted to 14.5 million units, with vehicle exports totaling 1.06 million units, making the United States the second in the world's automobile producing industry. Despite this, the automotive industry of the United States transforms toward NEV at a relatively slow pace. In 2020, NEV sales in the United States was only 324,000 units, accounting for only 10.12% of the global total, which is closely associated with Trump Administration's high dependence on fossil energy industry and little interest in the clean energy. During 2017-2020, the United States did not implement strong subsidy and preferential policy on electric vehicle, so that most automakers lacked interest in electrified deployment. As a result, market size of the NEV industry was relatively small, but Tesla

predominated in the industry. In 2021, the Biden Administration brought forth the US$ 2 trillion infrastructure plan to promote development of electric vehicle and clean energy. It is estimated that by 2025, sales of electric vehicles in the United States will hit 2.01 million units. The sales and growth rate of electric vehicles in the United States from 2018 to 2021 are shown in Fig.8.

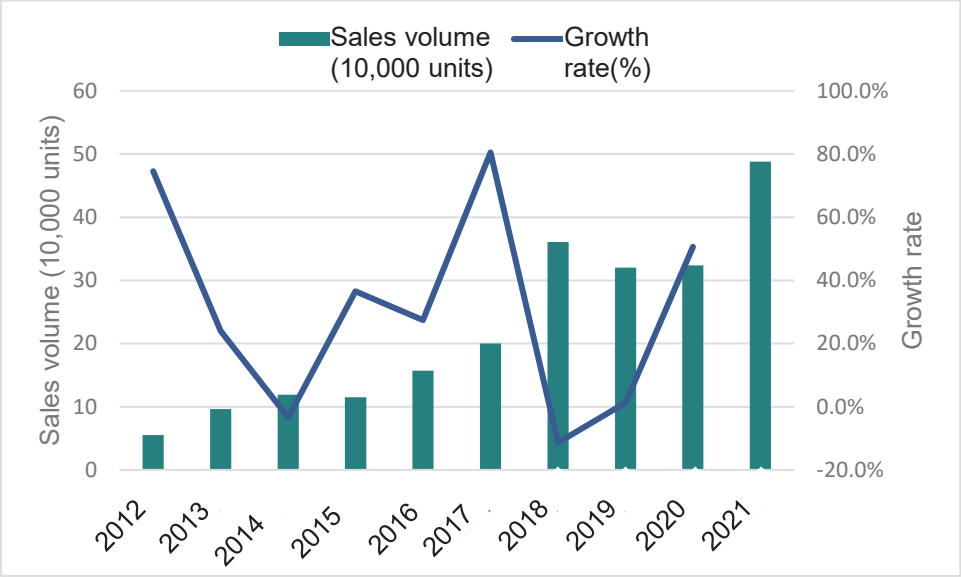


Fig. 8: Sales and growth rate of electric vehicles in the United States, 2018-2021

The United States is the first country in the world that guides and limits green development of the automotive industry and products. In 1975, the United States took into account limitation over automotive products' oil consumption, so that it established and adopted the Corporate Average Fuel Economy (CAFE) evaluation system, and passed, the *Energy Policy and Conservation Act* of the United States in the same year. In the following year, the United States required that automotive fuel economy label must be affixed on the vehicle before sales of a new vehicle. In 2007, the U. S. Congress passed the *Energy Independence and Security Act*, which set more stringent regulations on Corporate Average Fuel Economy standard and increased supply of renewable alternative fuels by instituting mandatory renewable fuel standard. According to the standard, transport fuel sold in the United States must contain at least 36 billion gallons of renewable fuels each year by 2022. Also, the United States created motor vehicle fuel economy standard credit trading plan, in order to push ahead with the implementation of fuel economy standard with flexible and market-oriented measures. In 2020, the U.S. Environmental Protection Agency and the National Highway Traffic Safety Administration (NHTSA) revised the updated light-duty vehicle GHG emission and fuel economy standard and formulated Safer Affordable

Fuel Efficient (SAFE) Vehicles Rule, stipulating that the United States will increase carbon dioxide emission standard by 1.5% each year during 2021- 2026. The U.S.'s management over oil consumption and GHG helped effectively promote the development of its automotive energy-saving technologies.

(2) Industrial Policy Design

For industries and enterprises, the United States has taken advantage of the market mechanism and government policies to keep promoting its energy independence and clean energy development since the beginning of the 21st century. Against the backdrop of complexity and volatility of international geopolitical situation, previous administrations of the United States adopted different measures, which, by and large, were aimed at reducing the U.S.'s energy dependence on foreign countries, increasing domestic energy supply, and diversifying energy supplies. As one of the key energy-consuming industries, the automotive industry has also been transforming toward a green and sustainable industry, but its development measures were clearly influenced by the competent authorities as different administrations practiced and interpreted the green development notion in their own ways.

During the Obama Administration, the United States successively promulgated its new-energy policy, automotive energy conservation & emission reduction plan, and Federal Government Innovation Strategy, and took the new-energy technologies as the foothold for implementation of its innovation strategy. The United States adopted active policies and financial support for technology R&D, industrialization, and popularization, used government procurement as the major support means and regarded the technological innovation and product R&D of NEVs as the core leading to industrial success. From 2008 to 2010, the U. S. government invested more than 2.4 billion USD in impelling NEV technological R&D and production, and boosting the production and popularization of supporting infrastructure. For example, the State of California promised that it would build a charging system with a capacity of one million electric vehicles by 2020, and install 300,000 charging piles in commercial zones of South California by 2030.

The Trump Administration focused on developing fossil energy and eliminating the barriers for the production of coal, petroleum, and natural gas. On June 1, 2017, the Trump Administration announced the U.S.'s withdrawal from *The Paris Agreement*. Regarding domestic policies, the Trump Administration lifted restrictions on oil and gas, and actively supported fossil energy production. Internationally, it promoted outbound sales of oil and gas, and actively expanded the export of fossil energy. In the meantime, it used oil and gas as a bargaining chip, and kept

capitalizing on the energy tool to achieve its national security and foreign policy goals. Since the Trump Administration showed little interest in developing new energy, the U. S.'s new-energy industry was faced with a severe market test during this period.

When Joe Biden took office, the Administration strongly implemented the "Green New Deal" and took the initiative to address climate change, announcing that the United States will invest about US$ 140 billion of subsidy and government investment fund in subsidizing electric vehicle, charging station, power grid reconstruction, and a portion of companies; it will set the ambitious goal of achieving net zero emission, and raise the average fuel economy efficiency to 52 miles per gallon of gasoline (10% higher than the standard set by the Trump Administration) in 2026, in order to reduce potential automotive emission. While executing more stringent fuel efficiency standard on the automakers, the United States raised the requirements about NEV sales, and set a goal that sales of electric vehicles, hydrogen fuel cell vehicles, and plug-in hybrid vehicles must account for 50% of the U.S.'s total car sales by 2030.

Since taking office, the Biden Administration strongly impelled relevant legislative work such as enacting *Build Back Better Act* (BBB Act). However, as there were too many disagreements between the two parties of the United States, the investment size of the BBB Act was curtailed to US$ 1.75 trillion after multiple rounds of deliberations and discussions. So far, the BBB Act has not yet been passed. In 2022, the United States rolled out the *Inflation Reduction Act* (IRA). Regardless of the changes of the Act's name or content, the Biden Administration remains supportive to the projects for energy and addressing climate change. For example, the up-to-date IRA will mainly increase the investment in energy security and climate change sectors: the United States plans to invest US$ 369 billion in clean electricity, emission reduction, increase of production subsidy for renewable energy and alternative energy, and support to NEV development, etc. According to the Biden Administration, the IRA will help the United States bring down its GHG emissions by about 1 billion tons by 2030, so that the U.S.'s GHG emission level will decline to 40% of the level of 2005, and the family that adopts clean energy and electric vehicle tax credit will save over US$ 1,000 per year.

The policies related to the green development of the U.S. automotive industry are shown in Table 6

Table 6: The U.S.'s policies on green development of the automotive industry

Field	Title	Key contents and objectives
Green design	*Product Liability Law*	Responsibilities shall be shared through product life cycle, in order to reduce impact of products on environment
	Resource Conservation and Recovery Act	It grants the Environmental Protection Agency the authority to control hazardous substances in different links such as hazardous substances generation, transportation, processing, and storage.
	National Environmental Policy Act	It provides to minimize the environmental pollution caused by End-of-life vehicles (ELV)
	Solid Waste Disposal Act	It stresses the cooperation between government and enterprises, encourages the use of advanced technologies in relation to substitution, material recycling, and reasonable reuse, etc., in order to reduce waste landfills to the greatest extent, and recover valuable energy from solid waste
	Toxic Substances Control Act	It strictly prohibits or limits the use of substances that could harm human life or damage the environment in the production.
Green supply chain	*Comprehensive Procurement Guideline*	It provides that products and services procured must be in conformity with national green certification standards.
	Strategic Plan for Transportation	It requires to develop the transportation industry on the premise of minimized harm on the ecology, nature and social environment.
	2025 Strategy for Development of National Transportation Technology	It requires to build a transportation system that is highly secure and intelligent and with minimum pollution.
	Guide for Management of Supply Chain Risks	Supply Chain Risk Management (SCRM) may be used for the purchase of products and service protection in all links of the supply chain
Green factory	*Energy Policy Act of 2005*	It encourages energy enterprises (including oil, natural gas, coal, and electric power enterprises, etc.) to adopt energy-saving measures.
	Inflation Reduction Act of 2022	It gives new EV/second-hand vehicle purchasers a tax credit of US$ 7,500/US$ 4,000; reconstructs existing automobile manufacturing facilities to produce clean vehicles (US$ 2 trillion)
Green product	*Corporate Average Fuel Economy Standard for Passenger Cars and Light Trucks for model years 2024-2026*	It sets a limit on light-duty vehicles' GHG emission, average fuel consumption, or economy. This Revision, which is the most rigorous fuel economy standard in the history of the United States, will exert more stringent assessment on the fuel economy in 2024-2026, and raise the minimum assessment standard for U.S. home-made cars' fuel economy and the penalty against nonconforming enterprises
	Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule	It raises carbon dioxide emission standard by 1.5% each year in 2021-2026
	Energy Policy and Conservation Act	It promotes the use of low-emission cars to save energy
	Transport Oil Product Consumption and GHG Emissions	It requires all automotive products in the market to be affixed with label for disclosure of products' oil consumption and GHG emission.

In terms of automotive design, the United States boasts complete environmental protection acts, product liability regulations, and state-level policies & regulations. For automotive hazardous substances and recoverability rate (ELV), *Product Liability Law* requires that responsibilities shall be shared through product life cycle, in order to mitigate the influence of products on environment. For automotive products in the market, the U.S. government will carry out stringent follow-up surveillance, and recall substandard products and implement rigorous punishment measures. *Resource Conservation and Recovery Act*(1984) grants the Environment Protection Agency (EPA) the authority to control hazardous substances in different links such as hazardous substances generation, transportation, processing, and storage. *National Environmental Policy Act* (2000) requires that environmental pollution caused by ELVs must be reduced to the maximum extent. *Solid Waste Disposal Act* and *Toxic Substances Control Act* (2002) require that waste landfills must be reduced as much as possible, and the use of hazardous substances must be strictly restricted. In terms of air pollution, multiple laws and regulations, including *Clean Air Act*, *National Emission Standards for Hazardous Air Pollutants, Maximum Achievable Control Technology*, and *Control Technique Guideline*, control the interior air and tail gas emissions from three aspects of technical guidance, process control, and terminal surveillance. EPA of the United States has listed out in detail the controlled materials, and those that use materials on the list in production must go through pre-use declaration and review process, and those violate this regulation shall be faced with enormous penalties.

The U. S. government developed its green procurement relatively early and has established a set of relatively full-fledged procurement rule, in order to actively promote the development of green market and green supply chain. For example, the United States has enacted nearly 20 executive orders of the president, including *Greening the Government Through Waste Prevention*, *Recycling, and Federal Acquisition* (No. 13101 Executive Order), *Final Guidance on Environmentally Preferable Purchasing for Executive Agencies*, etc. In addition, the Environmental Protection Agency promulgated the *Comprehensive Procurement Guideline* to guide the procurement of green products. In terms of green logistics, the United States rolled out *Strategic Plan for Transportation* and *2025 Strategy for Development of National Transportation Technology* at the beginning of the 21st Century, pointing out that it will build safe, high-efficiency, adequate, reliable, and environment-friendly transportation system. Thanks to years of development of the green logistics notion, the United States has greatly reduced pollution of the logistics on the environment.

Regarding ELV recycling, the United States did not have federal-level regulations, but conveyed the requirement about extension of product liability. In other words, all interested parties in product life cycle shall share responsibilities according to requirements of the *Product Liability Law*. In 2006, the U.S. Federal Government, state governments, and some industrial organizations jointly sponsored the National Vehicle Mercury Switch Recovery Program(NVMSRP), requiring that mercury-containing vehicle lamp switch must be removed first from parts after recovery of motor vehicles and before the motor vehicle is squeezed and shattered. Besides that, states in the U. S. have taken a variety of actions to promote the recycling of some parts, and 48 states have promulgated relevant regulations on recycling of end-of-life tires.

(3). Green Consumption of Products

Since January 1 2010, the U. S. Federal Government has put in place the individual income tax credit policy on taxpayers who purchase BEVs and plug-in hybrid electric vehicle. In the 2017 tax reform, the United States abolished multiple credit policies, except for the electric vehicle purchase credit policy. Firstly, the United States determines the discount based on battery capacity. According to the credit policy, a basic amount of US$ 2500 for tax credit is set for BEVs and PHEVs with a battery capacity of no less than 4kWh. For the part over 4kWh, tax credit amount will be increased based on the standard of US$ 417/kWh with an upper limit of US$ 7,500. Secondly, it sets a phasing-out mechanism that takes cumulative sales of automakers as the indicator. Since there is no clear deadline for individual income tax credit policy, the United States has set this phase-out mechanism for this preferential policy, so as to prevent automakers from over-depending on the government subsidy. According to this mechanism, the automaker shall withdraw from the product tax credit as from the following quarter after the automaker has reached a total sale of 200,000 units of vehicles. After the withdrawal, the automaker will no longer enjoy tax credit policy. Tesla and GM have both reached the phase-out line, and they began to withdraw from the tax credit respectively on January 1, 2019 and on April 1, 2019. So far, both Tesla and GM have completed the phase-out within one year, and they are no longer entitled to the individual income tax credit..

The support measures for new energy vehicles in the last three administrations of the United States are shown in Table 7.

Table 7: Supportive measures to NEVs by three administrations of the United States

Year	Then-president	New-energy policy details
2010	Obama	1) Tax subsidy and preference: Consumers who purchased BEV and PHEV after December 31, 2009 will enjoy a federal income tax discount of US$ 2,500 to US$ 7,500; In purchase of environment-friendly new car, those with a vehicle of less than 25 years of used time and of a CAFÉ below 18mpg, will enjoy subsidy of US$ 3,500-US$ 4,500; 2) Industrial support: It invested US$ 2 billion in supporting the R&D of battery pack and parts; stressed on construction of charging infrastructure; 3) fuel efficiency: a rise of 5% each year; 4) Join *The Paris Agreement.*
2019	Trump	1) Tax subsidy and preference: it canceled the Obama Administration's preferential policies ; 2) Industrial support: it revoked the State of California's clean vehicle plan; 3) Fuel efficiency: a rise of 1.5% each year; 4) It withdrew from *The Paris Agreement*, and instituted the America First Energy Plan
2021	Biden	1) Tax subsidy and preference: It has resumed the implementation of full-amount federal tax credit policy for purchase of electric vehicle, and added US$ 100 billion as consumer subsidy; It encourages consumers to get subsidy through replacing their used fuel vehicles with NEV; It grants automakers loan concessions to support their R&D. 2) Industrial support: It has invested US$ 174 billion in supporting the development of electric vehicles in the United States; It aims at building 500,000 electric vehicle charging stations by 2030; It invests US$ 45 billion in promoting the electrification of school buses and public buses. 3) Fuel efficiency: a rise of 1.5% each year. 4) Return to *The Paris Agreement,* and modify the Corporate Average Fuel Economy (CAFÉ) Standards

On the whole, the U.S. automotive industry's green development has gone through a trajectory of "up, fluctuate, and up" in recent years. When the notion of green development was still at the embryonic stage in the last century, the United States worked out relatively complete and detailed policies and regulations to promote the transformation towards green and low-carbon development. Although the differences in governance principles caused slow-paced green development in the U. S., the earlier start-up and massive policy incentives in recent two years have enabled the US to be leading in world's green development.

Chapter III Green Development of the Automotive Industry in BRI Participating Countries

Green and sustainable development has become the strategic focus of automakers. As concern over climate change and environmental deterioration spike, interested parties, including governments, consumers and investors, all work to the change the way the industry works, as well as its culture and products. That will exert far-reaching influence on the industry. Although substantial progress has been made, more efforts are still needed to realize sustainable growth in the industry.

1. Green Development of the Automotive Industry in Singapore

Due to the size of the country and constraints on resource and energy supply, the automotive industry in Singapore mainly focus on the consumer side and light industries (e.g., metallurgy, chemicals, oil refining, and electronics) at the inception phase of the life cycle, with no involvement in vehicle production. Statistics reveal that annual sales of the automotive industry in Singapore rose from 36,000 units in 2011 to 55,000 units in 2020, while the car parc rose from 610,000 units in 2005 to 920,000 units in 2019, showing an overall trend of growth that peaks in 2013 and is then followed by a slight decline, which implies that car parc in Singapore has reached a relatively high level within the country's carrying capacity. According to the data from Land Transport Authority of Singapore, electric vehicles (EVs) ownership in Singapore rose from 1,397 units at the end of 2020 to 3,713 units at the end of 2021, and registered EVs in Singapore accounted for 8.4% of new vehicles registered in the first five months of 2022.

Due to its unique geographical location, climate and environment, Singapore is a global leader and advocate of green development, with substantial experience in implementing the concept of sustainable development[10]. The Singapore Green Plan 2030, which was jointly promulgated by the Ministry of Education (MOE), the Ministry of National Development (MND), Ministry of Sustainability and Environment (MSE), Ministry of Trade and Industry (MTI), and Ministry of Transport (MOT), highlights Singapore's commitments under the UN *2030 Agenda for Sustainable Development* and the *Paris Agreement*, and enables the early realization of Singapore's long-term goal of zero-emission "under feasible conditions" as the country takes EV and corporate sustainable development as two of the five key pillars. On March 31, 2020, Singapore submitted its enhanced climate commitments, nationally determined contribution

(NDC), and long-term low-emission development strategy (LEDS) to the *United Nations Framework Convention on Climate Change (UNFCCC)*. Under the NDC, Singapore is committed to reaching peak emissions of 65 $MtCO_2e$ by around 2030. Building on the NDC, the country rolls out its LEDS which set a target of halving emissions from peak to 33$MtCO_2e$ by 2050, in hopes of realizing net zero emissions in the second half of this century.

According to Singapore's Voluntary National Review Report to the 2018 UN High Level Political Forum on Sustainable Development, further promoting an inclusive and sustainable industrialization process is one of Singapore's key initiatives based on the UN Sustainable Development Goals. However, Singapore is a small country with a manufacturing industry that is not well-developed and an automotive industry scale that is relatively small in scale. Green development of the automotive industry in Singapore is therefore centered on vehicle use and recovery and achieved through improving vehicle structure and promoting the use of clean energy and low-energy-consuming vehicles.

In the energy sector and the automotive industry, the Singapore government has prioritized the reduction of carbon footprints through clean energy use and energy efficiency improvements, setting a series of targets according to the timeline [10]. By 2025, the government will cancel the registration of diesel vehicles and install EV charger in all areas with HDB flats by 2025; by 2030, new vehicle and taxi registrations for non-clean energy vehicles will be halted, and 60,000 EV charging stations in will be built in Singapore's island; by 2040, internal combustion engine vehicles will be phased out according to the country's long-term vision, with all cars running on cleaner energy resources.

In terms of emissions control, the Land Transport Authority (LTA) introduced the Carbon Emissions from Vehicles Scheme (CEVS) to encourage consumers to purchase cleaner vehicles by offering rebates or imposing a surcharge based on the cleanliness of the vehicle's emissions. Based on carbon emissions, CEVS divides vehicles into 9 categories: A1~A4, B, and C1~C4. Vehicles with different levels of carbon emissions will receive subsidies or pay emission fines upon registration. For BEVs, 45% of additional registration fee (ARF), up to SGD 20,000, will be refunded to promote use of electric vehicles.

The scheme was revised three times in 2015, 2018 and 2021. Under the revised version implemented on 1 January 2018, the Vehicle Carbon Emissions Scheme (CEVS) was renamed as the Vehicle Emissions Scheme (VES), which requires disclosure of both the five vehicle pollutant profiles and the fuel economy of the vehicle and grading based on the worst performance

indicators for carbon emissions and pollutants. For new energy vehicles, emissions of upstream power production will be taken into account, and the vehicle's power consumption will be converted into carbon emissions via the electricity carbon emission factor 0.4g CO2/Wh. To assist the vehicle buyers in making an informed decision, Fuel Economy Labeling Scheme (FELS) requires mandatory information labels to be affixed to the cab of vehicles to provide fuel performance data and emissions data for each model.

To improve air quality, the government has introduced the Early Turnaround Scheme (ETS) to encourage vehicle owners to replace older diesel cars and buses with cleaner, greener models that meet the National Environment Agency (NEA) standards. Petrol vehicles that meet the replacement criteria need to comply with EUVI emissions standards. Under the ETS scheme, current quota premium (PQP) discounts are available for replacing existing vehicles with greener models.

Regarding tax policies [11], to encourage consumers to choose electric vehicle, the Government of Singapore will narrow the cost differential between electric and internal combustion engine vehicles. For example, the government adjusted the electric vehicle's lower limit of ARF to zero from January 2022 to December 2023, and modified the road tax on electric vehicles. Meanwhile, to reduce the shares of internal combustion engine vehicles in the market, the government will increase the tax rate for premium gasoline to 15 centers per liter, and increase that for mid-grade gasoline to 10 cents per liter. Meanwhile, the petrol duty rate will be increased by SGD 15 cents per litre for premium petrol and by SGD 10 cents per litre for midgrade petrol in order to gradually reduce consumer purchases of new internal combustion engine vehicles. For carbon emission in industrial production, Singapore is the first country in Southeast Asia to introduce a carbon tax policy. During the period from 2019 to 2023, Singapore levies a carbon tax of SGD 5 per ton of carbon dioxide equivalent emissions, in order to reduce energy consumption and carbon emissions. Such carbon tax regulation applies to all sectors not eligible for exemption, and is estimated to cover about 80% of the Island's total emissions. Singapore plans to review its carbon tax rate before 2023. The country will raise the carbon tax rate to SGD10-15 (equivalent to US$ 7.60-11.405) per ton of emissions by 2030, taking full account of global climate change, progress of the mitigation measures, and the island's economic competitiveness.

In terms of recovery, the government's recycling of industrial products will boost the industry's growth and create job opportunities with higher added value. Relevant departments have invested heavily in developing solutions to extract value and resources from key wastes and residual wastes,

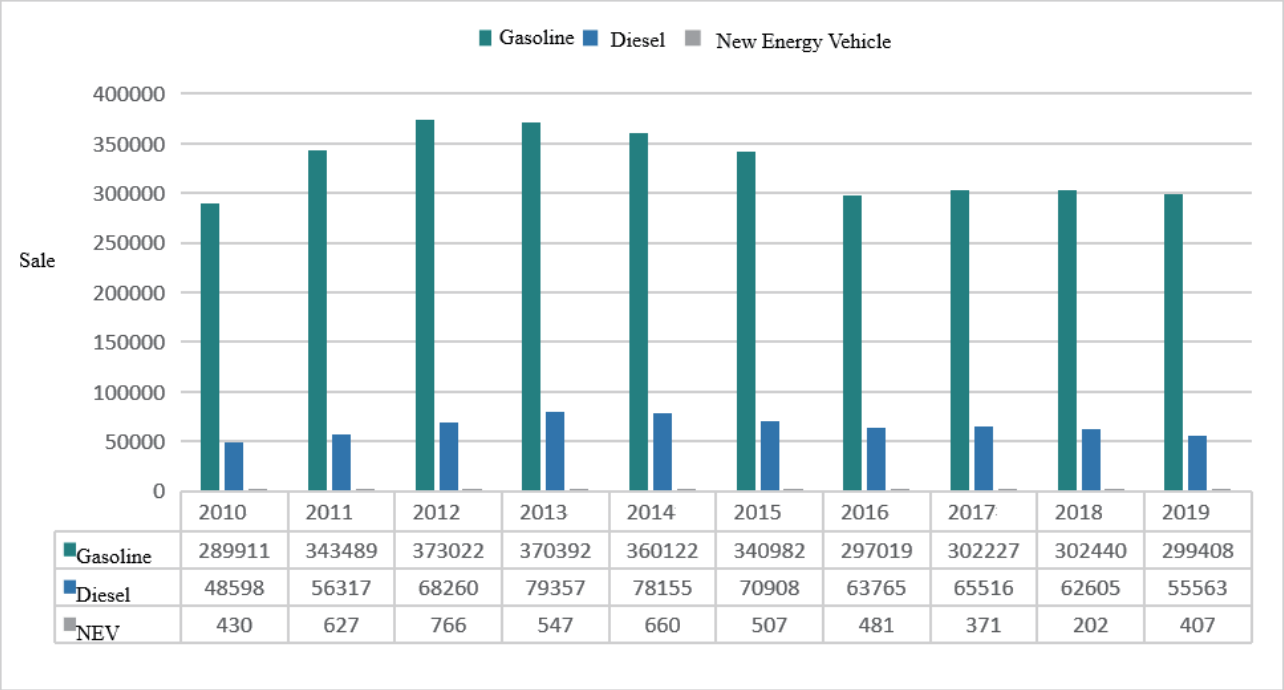
and have rolled out Environment Services Industry Transformation Map (ES ITM), in order to improve productivity, stimulate growth, and create better jobs for Singapore's cleaning and waste management departments.

The concept of sustainable development has taken root in Singapore due to its relatively advanced national economy and unique geographical environment. Since the automotive industry in Singapore is less involved in the manufacturing sector, Singapore's regulatory focus is on vehicle access, purchase and emissions, as a means of controlling the proportion of private transport, reducing vehicle-related pollutants and carbon emissions, and fostering the transition to sustainable transport.

2. Green Development of the Automotive Industry in South Africa

As the second largest economy in Africa, the Republic of South Africa is blessed with a high standard of living and a stable economy compared with other African countries. South Africa is ranked among the world's leading countries in the automotive industry and is one of the world's leading manufacturers, importers and exporters of automobiles and components. Almost all of the world-famous auto brands have built factories in the country. The automotive industry is also the most important manufacturing sector in South Africa. In 2010, South African government launched a new industrial policy action plan, which seeks to change its economic growth model, improve the competitiveness of the manufacturing sector, and actively boost the development of special economic zones and industrial parks.

From 2011 to 2019, South Africa's annual production and sales of the automotive industry fluctuated between 400,000 units and 500,000 units, with a rising trend at the beginning followed by gradual stabilization after 2015 and then some decline in both production and sales in 2020 due to the outbreak of the COVID-19 pandemic (see Fig.9). At present, South Africa is the only country in Africa that manufactures electric vehicles, but the number is few, with EV penetration rates in all provinces being less than 1%. [7]



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline	289911	343489	373022	370392	360122	340982	297019	302227	302440	299408
Diesel	48598	56317	68260	79357	78155	70908	63765	65516	62605	55563
NEV	430	627	766	547	660	507	481	371	202	407

Fig. 9: Annual sales of vehicles by category in South Africa, 2010-2019

In 2020, the automotive industry in South Africa, including the manufacturing, distribution, servicing and maintenance of vehicles and components, contributed 4.9% to South Africa's GDP (2.8% in manufacturing, 2.1% in retail), down from 6.4% in 2019, which should be attributed to influence of the COVID-19 and competent authorities' blockage policy on the automobile manufacturing and retailing. The automotive industry is the largest manufacturing industry in South Africa[12], with 18.7% of added value in domestic manufacturing output coming from automobile and auto parts manufacturing. South Africa ranks 22nd in the world in terms of automobile output and holds 0.58% of the global automobile market share[13]. Amid increase of FDI and trade, South Africa is committed to integrating its automotive industry into the global market for better growth. According to South Africa Automobile Master Plan (SAAM)[14], South Africa aims to produce 1% of the global automobile output (about 1.40 million units) by 2035.

For the industry as a whole, South Africa has put in place a green economic development framework, including the National Waste Management Strategy (NWMS) and Environmental Impact Assessment Regulations, to enable a green and sustainable transformation of the industrial system, with requirements for green development on the processing and production of raw materials, the general assembly of vehicles and the disposal of end-of-life products. Statistics from relevant documents show that South Africa has fulfilled the requirements for green development

throughout the life cycle of automotive products. Nonetheless, there are few specific documents with provisions on green development, whole most related provisions are requirements for the industry as a whole.

Since the government of South Africa attaches more and more importance to the alignment between industrial policies and environmental objectives, a series of changes have been made to relevant polices accordingly. In 2010, the Industrial Development Department of South Africa (IDC) set up green industrial sector service platform, marking the start of a gradual shift towards green industry in South Africa's Industrial Policy Action Plan (IPAP). Besides that, since 2016, IPAP has begun to devise policy roadmap for South Africa's climate-compatible industrial development.

South Africa's Environmental Implementation Plan (EIP) identifies sectors that may have an impact on the environment, and the policies, programs and plans involved, as well as how the sector complies with the National Environment Management Act (NEMA). Over time, the EIP has evolved from simply covering the day-to-day operations and management of the sector (e.g. improving the sector's waste management and carbon footprint) to considering how it can have a positive impact on the environment through its core functions (e.g. trade and investment programs). Besides, recognizing the need to integrate the development of green industries with the greening of existing economic activities, the Department of Trade and Industry (DTI) is formulating a set of action-oriented climate-compatible industrial development strategies for carbon-intensive industries such as steel and petrochemicals.

In terms of road transportation, South Africa's *National Climate Change Response White Paper*, as the guiding document, pointed out the need to foster a low-carbon and high-efficiency automotive industry in transportation [14]. According to the *Green Transport Strategy*[15] (GTS, hereinafter referred to as *Strategy*) issued by the Department of Transport of South Africa in 2018, the transportation industry has become the sector with the fastest growing GHG emissions in South Africa, contributing 10.8% of South Africa's GHG emissions, of which, road transport gasoline /diesel vehicles' direct emissions accounted for 91.2% of the industry's total emissions. Pursuant to the strategy, the Department of Transport of South Africa has enacted (or drafted) a series of measures to decarbonize the transportation sector: reduce carbon footprints and overdependence on oil-base fuel; encourage the use of alternative fuels (e.g., CNG or marsh gas) and liquid biofuel as transportation fuels; promote the adoption of electric, hybrid and fuel cell powered vehicles.

Moreover, relevant specifications, standards and regulations will also be studied and improved to promote the use of green fuels and raise the country's fuel emission standard. In addition, the country will institute *Green Procurement Guidelines* for South African government and departments concerned for increased adoption of high-efficiency and low-carbon automotive technologies in the state departments. The plan is to replace 5% of the vehicles used in the public sector and national departments with vehicles that use cleaner alternative fuels and high-efficiency technologies in the first 7 years since this strategy is implemented. On that basis, another 2% will be added each year thereafter till sustainable fuel vehicles are widely adopted.

In terms of regulation, South Africa enacted a more rigorous test scheme, requiring that all vehicles be tested at least once every three years, with waste gas emission inspection being a core item. The test will be directly associated with automotive license that is used to determine the vehicle's safety and emissions performance ratings. A regulatory system is also in place to tax vehicles based on emissions through an annual vehicle license renewal system. Moreover, South Africa introduced automotive life cycle concept in the road vehicles and a limit is set whereby vehicles with an engine running mileage exceeding 400,000km must be banned from the road or be scrapped.

Regarding fuel consumption, South Africa launched a fuel economy and carbon dioxide labeling project in 2016 under the framework of Green Transport Strategy, putting in place a mandatory labeling system for fuel economy(L/100km) and carbon dioxide emissions (g/km) for new passenger cars. Besides, it also plans to adopt more stringent fuel economy standards (e.g., Euro V) in the Green Transport Strategy in formulating new green standards. In 2016, the government enacted the Biofuels Regulatory Framework and the Government Electric Vehicle Procurement Policy to boost the development and sales of biofuels and electric vehicles in the country.

In terms of economic instruments, National Treasury of South Africa began to levy carbon tax on GHG emissions in June 2019. To be precise, an environment tax was levied on total combustion, process, and fugitive emissions alike. Carbon tax covers about 80% of South Africa's GHG emissions, making it one of the most ambitious carbon pricing schemes in the globe. In the automotive industry, the carbon tax on new vehicles is proportional to the vehicle's GHG emissions per kilometer, a move aimed at balancing the playing field between carbon-intensive and low-carbon emitting sectors. In the meantime, the government encourages consumers and enterprises to adjust their production and sales behaviors, as a way to reduce emissions.

In terms of new energy products, South Africa plans to develop green transportation such as EVs

and HEVs in 10 years' time. To address climate change, South Africa launched a NDC Draft at the end of March 2021 [16-17]. According to the draft, during 2021-2030, South Africa will focus on the decarbonization in the power sector (which is currently dominated by thermal power), and promote renewable energy such as solar and wind; during 2031-2040, South Africa will prioritize the development of green transportation, such as EVs and HEVs.

The Department of Transport of South Africa will work with the Department of Finance and the Department of Trade and Industry to launch a series of campaigns to promote the production and application of electric vehicles[18], with specific measures including: provide incentives to electric vehicle manufacturers; work with local research institutions on EV battery research; set the annual targets for the proportion of EVs and HEVs for government fleet vehicles; replace outdated vehicles of high emission factor with electric vehicles; formulate incentive measures on resource utilization in key machinery and/or parts (e.g., fuel cell) manufacturing; and assist in the establishment and development of local electric vehicle OEMs [17-18].

As one of the major countries in the international automotive industry, South Africa has taken actions towards green transition. However, most of these actions are still in their infancy due to constraints on its energy/resource structure and the actual national circumstances. The industry still has a long way to go in terms of industrial greening. It is also worth noting that South Africa's transition toward sustainability might aggravate existing social and economic challenges, and that, without appropriate policies and new green solutions, green products (e.g., EV and solar energy) only apply to high-income families and large-scale enterprises in the short run, which could deepen social divides and inequalities.

3. Green Development of the Automotive Industry in Portugal

Portugal is the first Western European country that has signed the MOU with China on BRI cooperation. As one of the main economic sectors in Portugal, the automotive industry contributes nearly 8.5% of the country's industrial output and 2.1% of its economic output, and thus is vital to Portugal's employment and export[19]. According to the data released by the International Trade Agency under US Department of Commerce in October 2021, Portugal's automotive industry, which consists of 32,200 automakers and parts manufacturers, has brought a total of 152,000 direct jobs, with employees accounting for 0.7% of the nation's workforce and 4.8% of the workforce in Portugal's manufacturing industry. The turnover of its automotive industry totaled 33.7 billion euros, equivalent to 21% of Portugal's total fiscal revenue. Automobile sales in Portugal from 2011 to 2021 are shown in Fig.10.

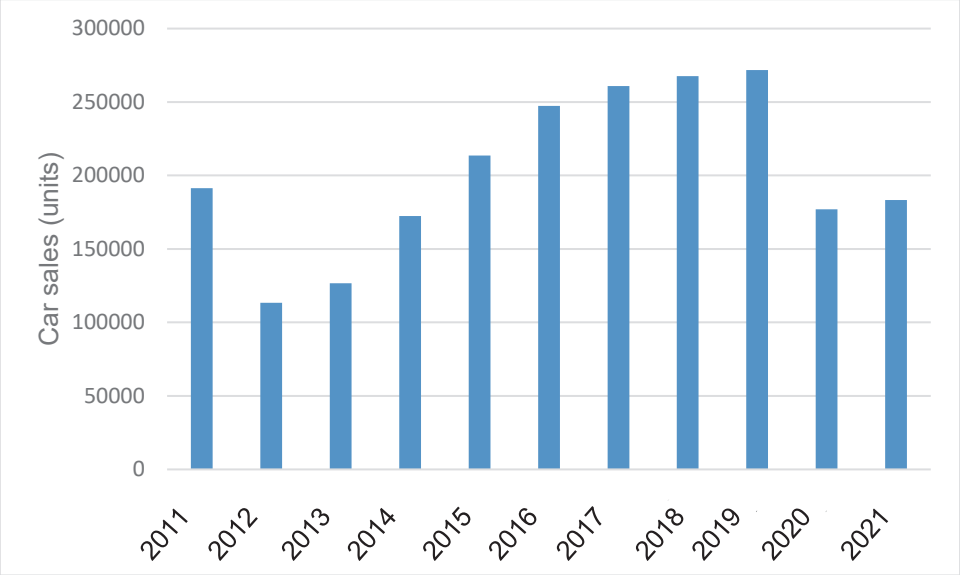


Fig. 10. Automobile Sales in Portugal, 2011-2021

Portugal is home to 220-odd automotive suppliers and four major automakers—Toyota/Salvador Caetano, PSA Peugeot Citroen, Mitsubishi Trucks, and Portugal's largesse automaker Volkswagen Auto Europa). Most of the automotive products manufactured in Portugal are exported to foreign countries, with an export value accounting for 97.9% of the automotive industry's total production value and 11% of the country's total export value. Europe is main destination of its exports, with the top 5 being Germany (20.4%), France(16.2%), Italy (11.7%), Spain (11.0%), and Britain(7.6%).

Portugal's automobile output totaled 294,366 units in 2018 and 345,688 units in 2019. Amid the COVID-19 pandemic in 2020, Portugal's automobile output still reached 260,000 units. In 2019, the Portuguese government became the 13th to submit its long-term low-emission development strategy (LTS) to the Secretariat of United Nations Framework Convention on Climate Change (UNFCCC), underlining its determination to realize carbon neutrality by 2050. Nearly 35,000 units of new-type alternative fuel vehicles (AFV) were registered in Portugal in 2020, accounting for 23% of Portugal's total vehicle sales that year, compared to 10.8% in 2019. Total sales of BEVs and PHEVs in Portugal approached 20,000 units in 2020, an increase of more than 55%. Sales of NEVs in 2021 hit 29,200 units, with a market penetration rate of 19.93%. [6]

In terms of top-level policies, Portugal's "Roadmap for Carbon Neutrality 2050 (RCN2050)"[7] sets forth the path to carbon neutrality, and identifies policies and measures needed to achieve this goal. According to Portugal's long-term strategy on low-emission growth, it's economically and technically feasible for Portugal to achieve carbon neutrality by 2050. Portugal aims to bring down its carbon emissions by 85%-90% by 2050 and offset the remaining emissions by ensuring a carbon sink capacity of around 13 million tonnes in agriculture and forestry. It is predicted that this strategy will bring emissions reductions of 45-55% by 2030 and 65%-75% by 2040. RNC2050 clarifies the future trend and necessary social & economic transition, including promoting research, innovation and knowledge production in the fields that are vital to achieving carbon neutrality, and providing effective conditions for different sectors (including energy, transportation, trade, services, industry, waste, agriculture, and forests) to monitor their progress and adopt carbon neutrality goals[20].

EV sales in Portugal have grown sharply since 2017. In 2020, PHEV sales accounted for 13.6% of Portugal's total automobile sales. Portugal's incentive measures for EV sales include government subsidies, tax benefits, and incentives for charging[21] (see Table 8).

[6] Source: ACEA and ACAP

[7] Roadmap for Carbon Neutrality 2050 (RCN2050): Long-term Strategy for Carbon Neutrality of the Portuguese Economy by 2050

Table 8: Portugal's incentive measures for EV sales

Field	Measures
Government subsidies	The European Commission approved a financial grant of 20 billion euros to provide incentives for consumers in 27 EU countries to purchase environment-friendly passenger cars; In 2021, Portuguese Government Environment Fund earmarked 4 million euros to encourage the purchase of EVs by both individual buyers and corporate buyers;
Tax benefits	BEVs priced below 62,500 euros and HEVs priced below 50,000 euros may be exempted from VAT in full amount; All BEVs are exempted from road tax; BEVs are exempted from corporate income tax, etc.
Incentives for charging	The Portuguese government is developing countrywide public EV charging network, ridding EV users of worries about the mileage when they drive in the country; It is expected that 20,000 charging stations will be installed by 2025.

Portugal's policy for the automotive industry is in line with the European Commission's plan to reduce CO_2 emissions from new cars sold in the EU to zero by 2035. Such a plan will effectively prohibit sales of automobiles equipped with gasoline/diesel engine. Portugal supports the EU's proposal that the automotive industry must modernize itself and prepare for new market needs.

In conclusion, the green transformation process of the Portuguese automotive industry is basically in sync with the EU, with actions taken in top-level design, product manufacturing, and product promotion, yielding much results with increased support for new energy vehicles. Nonetheless, as a country where the automotive industry constitutes an important part of the national economy, Portugal should further enhance its transition measures so as to seize new development opportunities.

4. Green Development of the Automotive Industry in Russia

Automobile production is a key industry in Russia, and provides Russia with more than 600,000 job opportunities, or less than 1% of Russia's total workforce. In 2021, Russia's automobile output totaled 1.49 million units. According to statistical data from the Ministry of Industry and Trade of Russia, the market share of Russia's home-made electric vehicles is basically zero, with about 11,000 electric vehicles out of a total of 45 million vehicles, representing a penetration rate of less than 0.02%. In recent years, the automotive industry in Russia has continued to decline due to internal and external factors such as the COVID-19 pandemic, chip shortage, and Russia-Ukraine Conflict[22]. Automobile sales in Russia from 2011 to 2021 are shown in Fig.11.

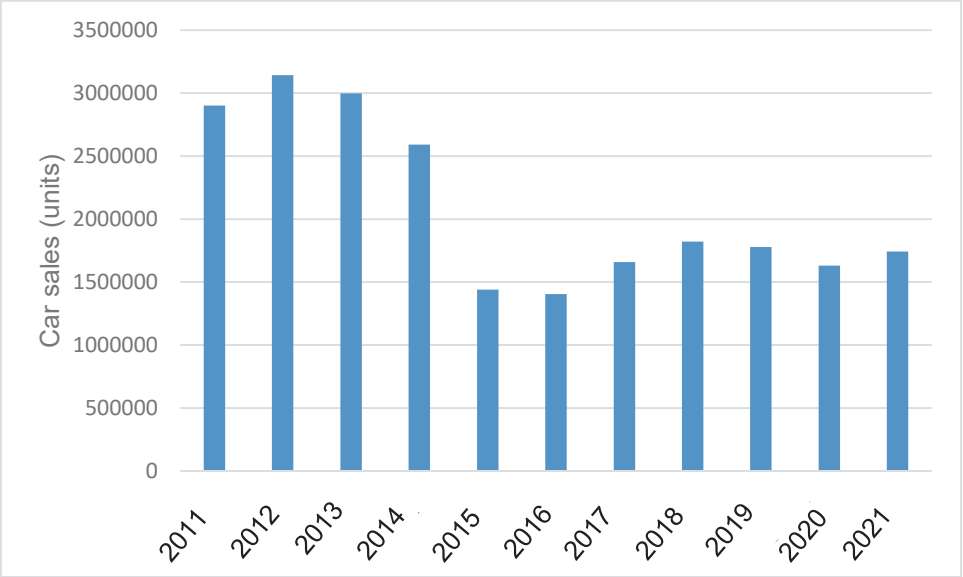


Fig. 11: Automobile Sales in Russia, 2011-2021

In 2021, Russia's GDP was USD 1.77 trillion, ranking 11th in the world, with median monthly salary of Russian people hitting RUB 51,200 (equivalent to around RMB 4,500). In the same year, sales of narrow-sense passenger cars in Russia amounted to 1.68 million units, which equals to 6.4% of passenger car sales in China and even less than annual sales of EVs in the mainland of China. The decline in volume and the slow-paced development of Russia automotive industry has become an objective fact.

For automobile manufacturing, Russia's vehicle manufacturing technology is relatively out of date, and relies partly on the production process and product lines in the Soviet era, with insufficient investment in the development of new technologies and slow progress in

technological upgrading. In addition, tundra accounts for 63% of Russia's territory, which, combined with national financial constraints, makes it difficult for Russia to carry out large-scale basic road construction. Moreover, the harsh operating environment has also hampered Russia's efforts to modernize its automotive industry. As a result, the automotive industry in Russia lags behind international advanced level, with an extensive mode of development in product design and industrial production.

In the last two years, due to severe sanctions from the Europe and the US, and a low level of localization (70-80% of parts for Russia's local automobile production depend on import), many automakers in Russia could barely continue effective production. According to overseas media reports, in order to maintain domestic automobile production and sales, the Russian government decided that local automakers are allowed to produce automotive products without complying to the emissions standards and vehicles are no longer required to be equipped with important safety kits (e.g., airbags, ESP, and ABS) till February 1, 2023.

Although the green transformation of the Russian automotive industry is currently lagging behind, Russia, as an important nickel producer, has also included new energy vehicles as one of the key emerging sectors for prioritized development under the global trend of energy conservation and carbon reduction as well as the shift of product lines to new energy sources. According to the *Research Report on Development of NEV in Russia* issued by the Ministry of Commerce of China[23], car parc of natural gas vehicles in Russia is small, with both market shares and penetration rate staying at a low level. However, consumption of natural gas for vehicle and construction of infrastructure (e.g., gas filling station) are growing at a faster rate. That's why experts in the industry are optimistic about the market prospect of the sector.

For electric vehicle, EV sales volume in Russia is limited due to the cold climate. Russia's EV sector mainly focuses on displaying new products and promoting innovative environmental ideas. So far, no local EV enterprise in Russia has successfully launched any EV model in mass production. In February 2022, Russian government noted that Zetta, a Russia-based company, would launch its first EV product, with an estimated sales price of RUB 450,000 (equivalent to RMB 42,600) a driving range of 200-360km, and a top speed of 120km/h. However, in view of Russia's gloomy EV market and infrastructure construction, we estimate that the actual launch date is not as optimistic as expected.

According to the *Development Plan for the Production and Adoption of Electric Vehicles* issued by Russia in 2021[24], Russia will earmark RUB 777 billion (equivalent to RMB 68.1 billion) to

develop the EV industry, which will be completed in two phases. In phase I, Russia plans to build at least 9,400 charging stations, of which 2,900 are fast-charging stations. In phase II, Russia plans to build at least 72,000 charging stations, including 28,000 fast-charging stations. More importantly, to assure uninterrupted driving of BEVs within its territory, Russia requires that the distance between two adjacent charging stations on the expressway shall be no more than 100km. Besides, the local government plans to boost local EV production and sales through a subsidy policy. For example, 25% of the total purchase price (up to RUB 625,000, equivalent to RMB 55,000) will be covered by the subsidy policy.

Russia has set ambitious goals for the green transformation of its automotive industry, and formulated grand plans for the development of EVs. But the achievement of these targets requires the renewal of the automotive industry's basic technologies and improvement of the country's economic strength. In recent years, the growth of Russia's automotive industry has fallen short of expectations, and even regressed to some extent. Now the country lacks core technologies in face of fierce global competition. As a result, the automotive industry in Russia still has a long way to go to realize green development.

5. Green Development of the Automotive Industry in Thailand

Thailand is one of the world's important automobile manufacturing bases, and its automotive industry's market is roughly the same size as that of established auto manufacturing countries (including France and the UK). Reputed as "Detroit in Asia", Thailand ranked 12th in terms of its automotive industry. The automotive industry is one of Thailand's pillar industries. Statistics show that in 2021, automobile output in Thailand totaled 1.72 million units, of which 960,000 units were exported, an increase of 30.35% compared to 2020. According to relevant sources, Thailand automotive industry is expected to achieve new growth in 2022, with total output hitting 1.80 million units (including 1 million units for export). Besides, car parc in Thailand will amount to 18.17 million units, which means car ownership per 1,000 persons will reach around 261 units, higher than that in China (214 units). According to data from Electric Vehicle Association of Thailand, Thailand's EV industry has begun to expand sharply since 2015. By 2019, 420 enterprises had been operating in Thailand's electric vehicle ecosystem, including multiple leading automakers such as Mercedes Benz, Toyota, Honda, and Mazda. Automobile sales in Thailand from 2011 to 2021 are shown in Fig.12.

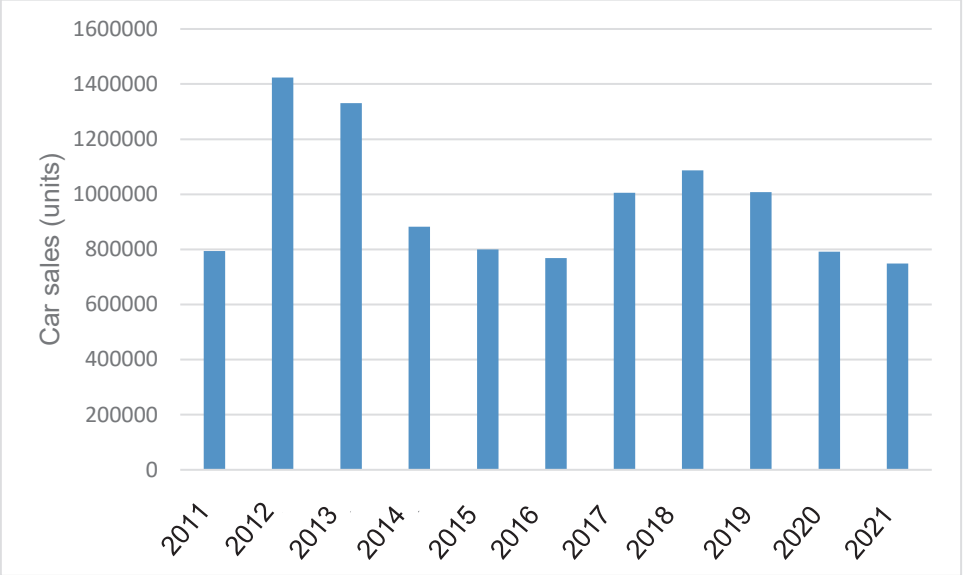


Fig. 12: Automobile Sales in Thailand, 2011-2021

With the rise of new-energy vehicles, the NEV industry has become part of Thailand's development strategy. In "Thailand 4.0" strategy, new-generation vehicles represented by NEVs have been included in the government's prioritized development industries. The government plans to increase its EV output to 30% of Thailand's total automobile output by 2030. In order to attract as much foreign investment as possible, the Thai government has offered generous tax incentives and reduced consumption taxes as well as taxes on imported production equipment, to encourage automakers to set up bases for electric vehicle production in Thailand. To enable continuous growth of the electric vehicle industry, the government of Thailand has set up the National Electric Vehicle Policy Committee. In March 2021, the Committee issued a master plan which proposes to build a complete EV industry chain and master advanced core technologies by 2035 with a focus on three major areas—zero-emission vehicles, next-generation automotive technology, and business model innovation. According to the Ministry of Higher Education, Science, Research and Innovation of Thailand, the government of Thailand strongly support the development of EV industry, and is committed to forge a NEV manufacturing center and export base for Southeast Asia. The timeline of EV development in Thailand is shown in Table 9.

Table 9: Timeline of EV development in Thailand

Stage 1	2016-2017	Formulate relevant laws & regulations and encourage the R & D of EV batteries; give priority to the manufacturing of 200 units of electric buses and large staff shuttle bus by Bangkok Bus Company, and build charging stations for electric vehicles.
Stage 2	2018-2020	Continue to promote R & D on EV batteries and drive units, and to expand the size of EV charging stations to meet the market needs.
Stage 3	2021-2035	Market-oriented and commercialized development of relevant research results.
Stage 4	After 2036	Replace oil-driven vehicles with NEVs in massive scale.

To achieve the vision above, Thailand Board of Investment rolled out a series of investment promotion incentive measures, including tax exemptions for automakers that produce more than one type of EV parts; tax exemption for up to 10 years for BEVs and up to 6 years for HEVs; reduction of NEV purchase tax and provision of vehicle purchase subsidies; establishment of project investment incentive fund worth USD 2.7 billion, etc. According to Thailand Board of Investment, automakers from multiple countries have applied for the aforesaid preferential policies, and the Board is deliberating the introduction of the second round of preferential investment policies. The supportive policies for Thailand's EV industry is shown in Table 10.

Table 10: Supportive polices for the EV Industry in Thailand

Fuel economy mode and energy-saving mode policy	At the end of 2018, the Ministry of Industry of Thailand began to examine the support policies for low-cost EVs with an annual capacity of more than 100,000 units of EVs are entitled to preferential policies, including exemption of import duties on production equipment, income tax exemption for up to 8 years, and a product consumption tax of 17%.
Preferential EV incentives	In 2019, the Cabinet of Thailand approved of the excise tax for electric passenger cars, and granted tax exemption with time limit or other conditions. In 2022, Thailand officially approved of new EV development measures, with significant reductions in tariffs, exercise duties, and market subsidies. Meanwhile, up to 40% of vehicle import tariff may be exempted.
EV investment policy	In 2017, Thailand Board of Investment enacted supportive policies for the production of HEVs, PHEVs, and EVs, etc.

In terms of environmental protection and energy conservation, the Thai government is actively promoting policies for energy-efficient and environmentally friendly vehicles in order to shore up

its position as a major ASEAN automotive production base. In Thailand, those who buy energy-saving and environment-friendly vehicles may be exempted from consumption tax, and the automakers can also enjoy preferential policies in income tax and import duties on production equipment.

Energy-saving and environment-friendly vehicles identified by the government of Thailand must first comply with the country's stringent oil consumption standard. The Thai government follows the European fuel consumption measurement method, the ECER101 model, to determine the fuel consumption of vehicles. Other standards for energy-saving and environment-friendly vehicles in Thailand include: oil consumption of no more than 5L/100km; exhaust gas emissions equal to or higher than Euro IV, and CO_2 emissions of no more than 120g/km; gasoline engine displacement of less than 1.3L, and diesel engine displacement of less than 1.4L.

Thailand's vehicle emissions are based on European vehicle emission standards, with Euro III standards applied since 2005 (equivalent to Thailand level 7 emissions standard applicable to gasoline vehicles, and Thailand level 6 emissions standard applicable to diesel vehicles). In 2012, Euro IV Standards are applied to both passenger cars and light trucks (equivalent to Thailand level 8 emissions standard applicable to gasoline vehicles, and Thailand level 7 emissions standard applicable to diesel vehicles). Since January 2012, more than 80% of Thailand-based oil refineries have been producing and selling gasoline and diesel fuels in line with Euro IV Standards.

On the whole, the automotive industry has become a major component of the Thai industry, and has officially entered into a golden period of industrial development. As one of the world's leading auto manufacturing/assembly countries, Thailand has enacted a series of measures, including setting EV output targets, adopting differentiated preferential policies at the consumption side, and encouraging infrastructure construction in the area of green development, so as to facilitate the automobile industry's transformation toward sustainable development.

6. Green Development of the Automotive Industry in Indonesia

Indonesia has become the second largest automobile manufacturer in ASEAN region, next only to Thailand. Low labour costs and a relatively large market space have attracted an increasing number of car manufacturers, including top tier international companies such as Toyota, Nissan and General Motors. The recent years have witnessed a rise in the preference for fuel-efficient vehicles in the Indonesian automotive industry due to factors such as climate change and changes in the energy mix. Automobile sales in Indonesia from 2011 to 2021 are shown in Fig.13.

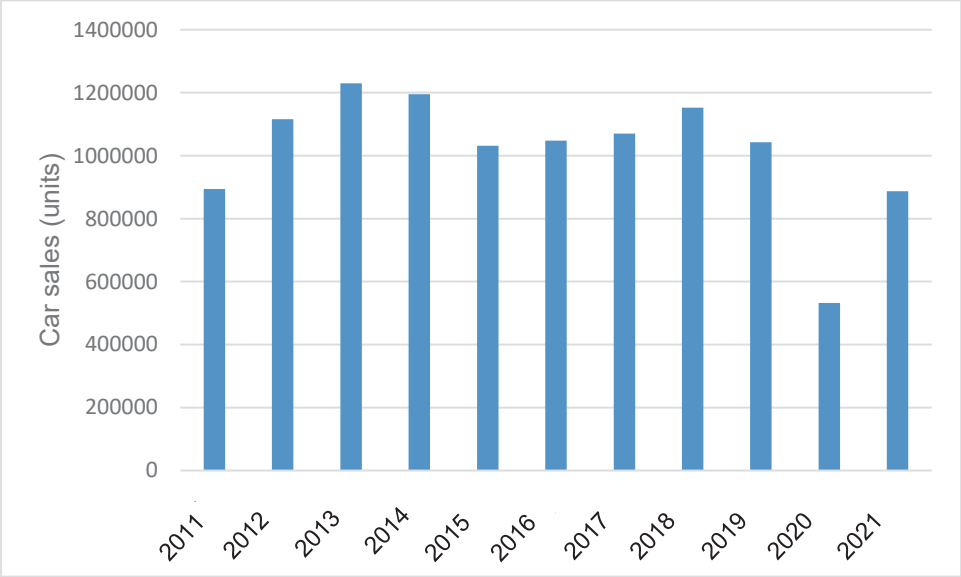


Fig. 13: Automobile Sales in Indonesia, 2011-2021

Relative to that in 2019, total sales of Indonesian automotive industry decreased by 48.4% in 2020, with only 530,000 units of vehicles sold. Passenger car was still the predominant sector in the industry, with market shares hitting 73.1%. In 2021, Indonesia sold about 3,200 units of NEVs, accounting for only 0.4% of total sales of new vehicles in Indonesia. During the spread of COVID-19 pandemic, Indonesia's GDP growth, consumer purchasing power, and growth of the automotive industry development have all been affected to varying degrees. The largest contributors to passenger car sales were the segments priced at 250 million rupees (approximately RMB113,000) and below, mainly two-wheel drive compact cars and low-cost green cars (LCGC). The Indonesian government is expected to develop a precise stimulus plan for the car industry as regulatory assistance is needed to support market purchases. Fiscal policies, including tariffs and import duties, could be considered in the context of protectionist measures implemented by

neighbouring countries to revive their domestic economies[25].

Indonesia's automotive industry has made a significant contribution to the growth of Indonesian economy. According to the Ministry of Industry of Indonesia, Indonesia automotive industry in 2021 saw an extraordinary double-digit growth (17.82%), creating direct jobs for 1.50 million people and indirect jobs for 4.50million people. Since the global pandemic has brought down production capacity of most industries, total output of Indonesia automotive industry declined sharply to 690,00 units in 2020. In the following year, 2021, however, the automotive sector grows rapidly again, with total production reaching 1.12 million units, almost twice as much as in 2020. It is predicted that 2022 will be another strong year for automobile production. Indonesia's total vehicle output (360,000 units) in the first quarter alone had exceeded half of the total vehicle output in 2020, and the growth rate is even higher compared with the figures for 2021[7].

The automotive industry alone contributed about 4% of Indonesia's GDP. Aside from the fast growth, Indonesia's automotive industry has manifested its competitive edge with its quality products. For example, Indonesia has made inroads into Australian market through export of 2 million cars. Australia is known for its stringent specifications and standards in relation to automobiles. Indonesia's success in entering Australian market exemplifies its huge potential in entering more overseas markets, especially neighbouring countries, making it a promising center for car production.

However, Environmental Performance Index (EPI) data released by Yale University in 2018 show that Indonesia ranks 133rd among 180 countries across the globe, which indicates that Indonesia's environmental performance is still low. The green development of the automotive industry, the industry with higher pollution emissions, deserve more attention from the government and industry practitioners. In Indonesia, quite a number of companies have carried out environmental practices far beyond environmental regulation requirements, in order to reduce energy consumption, promote green products or technologies among consumers, and minimize their ecological footprints.

According to Indonesia Automotive 4.0 plan, the automotive industry will go through three development phases by 2030, with the first phase up to 2021, during which the focus is still on the development of domestic production of internal combustion engine (ICE) vehicles, including strengthening raw material production capacity, improving productivity of ICE vehicles through the development of new technologies, and increasing domestic component manufacturing capacity and technology transfer. In Phase II (2021-2025), Indonesia will start with electric

motorcycles and set out a clear phase-out plan for fossil fuel-powered motorcycles. In the meantime, Indonesia will build required infrastructure and encourage the adoption of electric products, while building R & D centers for EV parts (particularly battery products), so as to enhance the localization capabilities along the entire value chain. In Phase III (2025-2030), Indonesia will begin to manufacture EV products at home and set a clear phase-out plan for ICE vehicles. More efforts will be made to build and encourage the use of EV infrastructure, while encouraging the continuous improvement of relevant parts. Indonesian government plans to replace all new motorcycles with electric motorcycles by 2040, and replace all new motor vehicles with electric vehicles by 2050 [25]. The master plan on the green transformation of Indonesian cars is shown in Table 11.

Table 11: Master plan on the green transition of the automotive industry in Indonesia

Regulatory framework	UU3/2014; PP14/2015; PP41/2015; PP41/2013; 30/2017
Goals	Support Indonesia to cut carbon emissions by 29% by 2030; Support Indonesia's energy goals for 2025 and 2030; Ensure that the development of Indonesia's automotive industry keeps pace with the international market.
Strategies	Carbon reduction via ICE technology; Carbon reduction for hybrid vehicles (including PHEVs and HEVs); Zero-carbon technology (including BEVs and FCEVs).
Challenges	Further localize automotive components to improve trade balance; Institute incentive measures to encourage local production; Influence on existing industries and investment; Create new supply chains for electric the main components of EVs; Customer acceptance of new technologies.
Progress	Some industrial provinces work with Mitsubishi Motors to jointly research EV technology and promote its social use; Comprehensive research on EVs between Toyota and research institutes (e.g. colleges and universities);

Although EVs are available in Indonesia, its EV sector still largely depends on import, with some being complete vehicles and others being locally assembled products with imported parts. Regarding localized manufacturing, Indonesia also makes positive changes. It is currently promoting the development of EV-related industries, in order to speed up development of the

manufacturing industry and reduce air pollution, traffic noise, as well as the dependence on imported gasoline. In March 2021, Indonesia introduced an EV battery plant launched by South Korea's Hyundai Motor and LG Energy Solution, a step toward the development of a complete EV supply chain in Indonesia. It is planned that all locally produced EVs will be equipped with batteries and other key parts made in Indonesia, making full use of Indonesia's abundant mineral resources.

However, at present, according to national financial authorities, the cost of purchasing an electric car for the Indonesian people is almost twice that of a conventional gasoline car; when taking into account the total cost of ownership (i.e. purchase, maintenance and energy supply over a ten-year period), the price of an electric car remains 1.4 times that of a gasoline car. In the absence of a carbon pricing mechanism, other economic measures are needed to reduce the cost of electric vehicles, including cash subsidies and tax exemptions (VAT, import taxes) for new electric vehicles, reduced petrol subsidies, and enhanced infrastructure.

To sum up, Indonesia has taken full actions and formulated plans for green development of the automotive industry. It intends to build a green and sustainable industrial chain for the automotive industry. However, confined by its industrial structure, economic cost, and technological development, Indonesia still has a long way to go to complete its green transformation.

Chapter IV Status Quo and Problem Identification

1. Incentive Measures are Introduced by Different Countries

In recent years, countries across the globe have successively rolled out incentive measures to support the automotive industry's transition. Many automakers have issued their new energy development plans, and a growing number of sci-tech enterprises have begun to enter the NEV sector. Analysis results show that the automotive industry continues the development trend toward digital, intelligent, and green technologies, which will help promote sustainable development of global transportation, and foster the green recovery of different economies.

In the Outline of the 14th Five-Year Plan and Vision 2035, China proposed to focus on strategic emerging industries such as NEV, "expedite innovation and application of key and core technologies, enhance the ability to guarantee factors of production, and foster new drivers for industrial development". Local governments have enacted measures to support development of NEV, including measures to promote the sales of NEV in rural areas and assure the energy supply of manufacturing enterprises. Such measures helped boost the industry's fast growth. As of the end of 2021, China had built a total of 75,000 charging stations, 2.617 million charging piles, and 1,298 battery swapping stations.

The French government launched a plan to revitalize the automotive industry in 2020. According to the plan, consumers can enjoy an ecological bonus for purchasing new and second-hand EVs. The governments of Ireland, Canada, and Japan announced plans to ban the sales of new fuel-powered vehicles by 2030 or 2035. The UK expedited its deployment of the power battery industry… According to the report from the International Energy Agency (IEA), many countries have rolled out car purchase subsidies during the pandemic, which strongly supported the development of the EV market.

BRI participating countries have also embraced such a change. Singapore promoted the application of NEVs and energy-saving vehicles through the "Vehicle Emission Scheme" and "Early Turnover Scheme". South Africa formulated a full-fledged green development plan that covers energy, production, and consumption. Russia gradually established two paths for the coordinated development of natural gas vehicles and EVs despite its slow-paced green transition. Indonesia also built up low-carbon vehicle manufacturing processes on the entire supply chain.

Data show that a growing number of developing countries have quickened their steps in their deploying in the NEV market. Through cooperation with China, Egypt launched its first locally

produced EV; Kenya plans to increase the market shares of EV to 5% by 2025, and to set up charging piles in new buildings; Malaysia announced tax exemption policies for all EVs on sell in its 2022 Fiscal Budget; Chile made electric mobility a national strategy; and Argentina is actively urging the Congress to deliberate and approve the Sustainable Transportation Act. Green transition has become a mainstream trend for development of the global automotive industry.

2. The Trend Towards Electrification Continues to Grow

NEV is regarded as an important sector for the green growth and low-carbon transition of global automotive industry. World Bank suggests that, given all transportation costs such as vehicle/fuel/operation expenses and losses arising from traffic congestions, the global transition toward sustainable transportation will save USD 70 trillion by 2050. The rating agency Standard & Poor estimated that EV sales will account for 7%-10% [26] of the world's total automobile sales in 2022, and the trend toward electrification transition in the automotive industry will continue to strengthen.

The world's NEV industry began with hybrids, and then centered on the BEVs. After that, BEVs and PHEVs became the dominant products supported by NEV-related policies. Since 2013, with the implementation of incentive policies by different countries, NEV industry have witnessed rapid growth. In 2021, sales of new-energy passenger cars (including BEVs, PHEVs, and FCEVs) amounted to 6.23 million units, representing a year-on-year increase of 118.6%. In recent years, under the pressure of limiting carbon emissions, various countries kept strengthening their policy support for NEVs. As a result, shares of NEV in the automotive market rose year by year. In 2021, shares of new-energy passenger cars in the passenger car market rose to 8.5%, up by 4.8 percentage points from 2020.

In an article published in *Forbes* magazine, German big data expert Bernard Marr points out the three major trends that the transportation industry will face in the future: electrification, automation, and servitization. At present, some European automaker have turned to upstream supply chain as the focus of their green transition, such as steel manufacturing, new energy development, and recycling of rare metals. The world-famous automaker Volvo Cars has begun to source steel products with low carbon emissions, while German BMW Group also invested in steelmaking startups with low carbon emissions in the United States.

3. Uneven Development in Different Countries

Today, the world has reached a consensus to address climate change and expedite green transition of the automotive industry. However, confined by multiple factors such as the level of economic development, the geographical location of the country, and the R&D capability for core technologies, countries across the globe vary in the pace of green development, which are manifested in the following ways.

1) Lack of systematic and concrete top-level design. On the whole, BRI participating countries all brought forth relevant requirements and strategic objectives at different stages, such as low-carbon product design and green manufacturing transition, but there are certain gaps between the strategic objectives and their implementation, without clear and specific paths identified to achieve the objectives, which makes it difficult to carry out practical work, resulting in sluggish green development.

2) The speed of development is confined by the level of the economy. Experiences show that good development momentum and full-fledged industrial scale of the automotive industry are the key to green development; the underlying economic foundation can effectively support the high expenses for the development of new technologies and new products. For this reason, countries/regions with a good performance in green development are mainly developed countries/regions (e.g., the EU and the United States) and emerging economy such as China. Such a conclusion is also fully exemplified by our survey on BRI participating countries: countries with a large automotive industry and well-developed economy are often able to define their own new-energy or energy-saving development paths, whereas countries with a weak industrial foundation perform poorly in green development.

3) Infrastructure construction is lagging behind. Globally, inadequate new-energy infrastructure across the globe is one of the important factors that have hindered the development of relevant automotive products, and thus infrastructure construction is one of the key tasks at this stage. The European Union plans to build one million public charging piles by 2025; the United States plans to invest USD 141 billion to enhance its EV infrastructure; China also proposes to build a relevantly advanced infrastructure. The gap is more evident in developing countries, leading to sharp increases in the cost of car use and declines in the market purchase willingness, which hampered the industry's green transition.

4) Small size of green investment. At present, the world green industry develops at an accelerated rate. Against this backdrop, many countries are quickening the pace of institutional innovation

and technological reform to boost the transformation and upgrading of the economy, energy and industrial structure, in a bid to realize economic and social sustainable development. However, the green investment is closely associated with countries' economic development. As the green economy is still an emerging concept, most investments in green economy were made by developed countries/regions such as Europe and America. Faced with multiple weaknesses in policy-making and financial support, BRI participating countries need to win supports from multiple parties via international cooperation.

Chapter V Conclusion and Recommendations

The report proposes the following recommendations on country level, industry level and enterprise level.

1. Country Level

Enhance international cooperation on the green development of the automotive industry under the framework of the BRI. China has made remarkable progress in the green development of the automobile industry with a well-developed policy system, success cases at both industry and enterprise level, and rich experience in the development and application of energy conservation and carbon emission reduction technologies throughout the industrial chain. Therefore, China should make full use of the BRI to share experience with BRI participating countries, push ahead with technology R&D and industrial transition, and work together with BRI participating countries to jointly promote the low-carbon and high-quality development of the automobile industry.

Support the development of the NEV industry. As the main engine for the sustainable development of the global automotive industry, NEV is the future for automakers with fierce competition among countries. Therefore, BRI participating countries could step up their support for NEVs with due consideration to local and international circumstances. Through formulating plans and improving the mechanisms for the development of the NEV industry, BRI participating countries could overcome existing obstacles, create a favorable policy environment for the development of NEVs, seize new opportunities in the new era, and accelerate the development of the domestic automobile industry.

Improve policy development and implementation for the automotive industry. The green development of the automobile industry involves multiple processes, including energy & resources, material exploitation, manufacturing & processing, vehicle production, road drive, and scrapping and recycling. Under the overall strategic framework, specific policy guidance for different fields and by stage/cycle/process is necessary for promoting the green transition of the whole industrial chain.

Step up technology exchange and cooperation in the new energy industrial chain. An analysis of the six BRI participating countries shows that one of the obstacles for the green development of the automobile industry is the lack support from infrastructure and upstream industries. For

instance, Thailand and Indonesia, though relatively developed in vehicle manufacturing, but lag behind in the development of supporting industries, which brings uncertainty to the future. Therefore, it is important to take actions on national level to promote industrial and technology transfer.

2. Industry Level

Improve the roadmap for the green transition of the automotive industry. China has issued a series of guideline documents to support the development of the automobile industry, including *NEV Industry Development Plan (2021-2035)* and *Technology Roadmap for Energy-saving and New-energy Vehicles 2.0*, proposing clear and detailed recommendations on the development path and technical route, etc. It is recommended that BRI participating countries learn from the experience and practices of China and developed countries and formulate development plans for the automobile industry based on their own realities to identify existing problems and future development paths.

Foster industrial organizations to guide green development. In the current stage, BRI participating countries still have a long way to go in pursuing green development. The lack of clear rules, regulations and development paths makes it difficult for enterprises to implement related policies. To solve the problem, government departments could foster independent third party research organizations to provide technical support and planning for different enterprises to facilitate their green transition. Related policies should also be upgraded on time in response to the changing reality to ensure maximum effect of policy implementation.

Enhance talent development in the automotive industry. It is important to improve capacity building and talent training for the green development of the automobile industry with the engagement of industrial authorities and corporate representatives, so as to establish a full-fledged talent reserve system.

Strengthen fiscal, financial, and tax supports to the construction and application of battery charging/swap infrastructure. Priorities should be given to make charging more convenient and cheaper, so as to attract consumers to purchase NEVs. First of all, policies should be issued to support the construction of battery charging/swap infrastructure, including providing financing and subsidies. Second, measures should be taken to reduce the cost of battery charging, including providing favorable electricity fare for EV owners and establish free or low-cost charging stations that are open to the public.

3. Enterprise Level

Improve capacity building for green manufacturing. BRI participating countries BRI participating countries are faced with multiple challenges. First, they are still in the early stage of the construction of the green manufacturing system; second, their automakers lack management experience in energy conservation and carbon emission reduction; third, they have a relatively weak industrial foundation and are in need of capacity building. Based on China's policy system, regulations, and standards with reference to international good practices and experience, Chinese enterprises could cooperate with automakers in BRI participating countries in green and low-carbon development planning, green material and equipment purchasing, process & flow optimization, and recovery system improvement, etc., which in turn, helps advanced Chinese technologies to go global.

Develop NEV products based on local reality. automakers in different countries should take into account their own geographical conditions and technological development achievements to give full play to their strengths, and deploy their competitive NEV products in advance, for example, Japan gives priority to the development of hydrogen energy vehicles, whereas Russia chooses natural gas as the fuel and vigorously develops natural gas vehicles.

Guide the automotive industry's green investment and financing: It is important to make full use of BRI participating countries' advantage in environment, policy, resources and manpower to attract advanced enterprises to build factory in dependently or in collaboration with local enterprises, carry out investment and financing, bring in advanced technologies, assist local enterprises in acquiring advanced development experience, and strengthen economic and trade ties with related countries.

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Appendix 1 China Eco-car Certification Index System

Annexed Table 1.1: Distribution of Points in Conventional Energy Passenger Car Certification System

<table>
<tr><th colspan="2">Certification item</th><th colspan="6">Contents</th></tr>
<tr><td rowspan="10">Health(50)</td><td rowspan="9">In-car air quality(30.0)</td><td>Testing at room temperature(10.0)</td><td>Testing at high temperature(10.0)</td><td rowspan="9">Odor evaluation at room temperature(6.0)</td><td rowspan="9">Odor evaluation at high temperature(4.0)</td></tr>
<tr><td>Benzene(2.0)</td><td>Benzene(2.0)</td></tr>
<tr><td>Methylbenzene(1.0)</td><td>Methylbenzene(1.0)</td></tr>
<tr><td>Dimethylbenzene(1.0)</td><td>Dimethylbenzene(1.0)</td></tr>
<tr><td>Ethylbenzene(1.0)</td><td>Ethylbenzene(1.0)</td></tr>
<tr><td>Styrene(1.0)</td><td>Styrene(1.0)</td></tr>
<tr><td>Methanal (2.0)</td><td>Methanal (2.0)</td></tr>
<tr><td>Ethanal(1.0)</td><td>Ethanal(1.0)</td></tr>
<tr><td>Acrolein(1.0)</td><td>Acrolein(1.0)</td></tr>
<tr><td>In-car noise(20)</td><td colspan="2">Driving at idle speed (4.0)</td><td>Driving at even speed of 60km/h (10.0)</td><td colspan="2">Driving at even speed of 120km/h (6.0)</td></tr>
<tr><td>Low-carbon (20)</td><td>Carbon emissions in car life cycle(20.0)</td><td colspan="6">-</td></tr>
<tr><td rowspan="3">Environmental Protection(30)</td><td>Hazardous substances(10.0)</td><td colspan="3">Lead content of vehicle hazardous substances(5.0)</td><td colspan="3">Lead content of vehicle per unit of mass(5.0)</td></tr>
<tr><td>Tail gas emissions(18.0)</td><td>CO (3.0)</td><td>THC(3.0)</td><td>NO_X(3.0)</td><td>PM (3.0)</td><td>PN (3.0)</td><td>N_2O(3.0)</td></tr>
<tr><td>Recoverability & recyclability(2.0)</td><td colspan="6">Calculation of two rates(2.0)</td></tr>
</table>

Annexed Table 1.2 Distribution of Points in BEV Certification System

<table>
<tr><th colspan="2">Certification item</th><th colspan="4">Contents</th></tr>
<tr><td rowspan="10">Health(56)</td><td rowspan="9">In-car air quality(34.0)</td><td>Testing at room temperature(12.0)</td><td>Testing at high temperature(12.0)</td><td rowspan="9">Odor evaluation at room temperature(6.0)</td><td rowspan="9">Odor evaluation at high temperature(4.0)</td></tr>
<tr><td>Benzene(2.4)</td><td>Benzene(2.4)</td></tr>
<tr><td>Methylbenzene(1.2)</td><td>Methylbenzene(1.2)</td></tr>
<tr><td>Dimethylbenzene(1.2)</td><td>Dimethylbenzene(1.2)</td></tr>
<tr><td>Ethylbenzene(1.2)</td><td>Ethylbenzene(1.2)</td></tr>
<tr><td>Styrene(1.2)</td><td>Styrene(1.2)</td></tr>
<tr><td>Methanal (2.4)</td><td>Methanal (2.4)</td></tr>
<tr><td>Ethanal(1.2)</td><td>Ethanal(1.2)</td></tr>
<tr><td>Acrolein(1.2)</td><td>Acrolein(1.2)</td></tr>
<tr><td>In-car noise(22.0)</td><td colspan="2">Driving at even speed of 60km/h (11.0)</td><td colspan="2">Driving at even speed of 120km/h (11.0)</td></tr>
<tr><td>Low-carbon (26)</td><td>Carbon emissions in car life cycle(26.0)</td><td colspan="4">-</td></tr>
<tr><td rowspan="2">Environmental Protection(18)</td><td>Hazardous substances(16.0)</td><td colspan="2">Lead content of vehicle hazardous substances(8.0)</td><td colspan="2">Lead content of vehicle per unit of mass(8.0)</td></tr>
<tr><td>Recoverability & recyclability(2.0)</td><td colspan="4">Calculation of two rates(2.0)</td></tr>
</table>

Annexed Table 1.3: Distribution of Points in PHEV Certification System

<table>
<tr><th colspan="2">Certification item</th><th colspan="6">Contents</th></tr>
<tr><td rowspan="10">Health(50)</td><td rowspan="9">In-car air quality(30.0)</td><td colspan="2">Testing at room temperature(10.0)</td><td colspan="2">Testing at high temperature(10.0)</td><td rowspan="9">Odor evaluation at room temperature(6.0)</td><td rowspan="9">Odor evaluation at high temperature(4.0)</td></tr>
<tr><td colspan="2">Benzene(2.0)</td><td colspan="2">Benzene(2.0)</td></tr>
<tr><td colspan="2">Methylbenzene(1.0)</td><td colspan="2">Methylbenzene(1.0)</td></tr>
<tr><td colspan="2">Dimethylbenzene(1.0)</td><td colspan="2">Dimethylbenzene(1.0)</td></tr>
<tr><td colspan="2">Ethylbenzene(1.0)</td><td colspan="2">Ethylbenzene(1.0)</td></tr>
<tr><td colspan="2">Styrene(1.0)</td><td colspan="2">Styrene(1.0)</td></tr>
<tr><td colspan="2">Methanal (2.0)</td><td colspan="2">Methanal (2.0)</td></tr>
<tr><td colspan="2">Ethanal(1.0)</td><td colspan="2">Ethanal(1.0)</td></tr>
<tr><td colspan="2">Acrolein(1.0)</td><td colspan="2">Acrolein(1.0)</td></tr>
<tr><td>In-car noise(20.0)</td><td colspan="4">Driving at even speed of 60km/h (10.0)</td><td colspan="2">Driving at even speed of 120km/h (10.0)</td></tr>
<tr><td>Low-carbon (20)</td><td>Carbon emissions in car life cycle(20.0)</td><td colspan="6">-</td></tr>
<tr><td rowspan="3">Environmental Protection(30)</td><td>Tail gas emissions(18.0)</td><td>CO (3.0)</td><td>THC(3.0)</td><td>NO_X(3.0)</td><td>PM (3.0)</td><td>PN (3.0)</td><td>N_2O(3.0)</td></tr>
<tr><td>Hazardous substances(10.0)</td><td colspan="3">Lead content of vehicle hazardous substances(5.0)</td><td colspan="3">Lead content of vehicle per unit of mass(5.0)</td></tr>
<tr><td>Recoverability & recyclability(2.0)</td><td colspan="6">Calculation of two rates(2.0)</td></tr>
</table>