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High-Quality Development of the Petrochemical Industry in China

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Abstract: The petrochemical industry is a pillar of China's economy and an important field that supports the high-quality development of the manufacturing sector. This study examines China's petrochemical industry using field research, seminar discussions, and document analysis methods. Although China is at the forefront of petrochemical development, the development quality of the petrochemical industry still needs improvement, product supply is insufficient, and technological innovation is lacking. For China's petrochemical industry to reach the middle and upper echelons of the global industrial and value chains, top-level designs should be improved to upgrade the industry's quality and efficiency, and a market-oriented capacity control mechanism should be established to shift the driving forces for development. Moreover, China should focus on technological innovation to promote core competitiveness, optimize its domestic business environment to facilitate fair competition, improve environmental policies to promote safe and green transformation and deepen international cooperation among the Belt and Road countries.

Keywords: petrochemical industry; high-quality development; structural adjustment; transformation and upgrading

1 Introduction

Having entered the stage of high-quality development, China now pursues high-quality development as the main theme of economic and social development to accelerate the construction of solid manufacturing power [1]. As an essential part of the manufacturing and key industries, the petrochemical industry plays a vital role in promoting China's high-quality economic development, stabilizing economic growth, meeting the growing needs of residents for better life quality, and safeguarding national energy security. After more than 70 years of development, China's petrochemical industry is characterized by a modern, comprehensive industrial system with complete categories, various supporting facilities, advanced technology, and strong competitiveness. China has become a major global source of petrochemical power.

With unprecedented changes in the past century, a new round of technological revolution and industrial reform is advancing by leaps and bounds. The world is undergoing a new stage of rapid development, transformation, and adjustment, in which China offers an important strategic opportunity for development. Starting from the new development stage, China should implement the new development concept, build a new development pattern, and promote the high-quality development of the national economy. In this context, China's petrochemical industry will face new opportunities and challenges. With the support of the consulting project of the Chinese Academy of Engineering, this study was conducted to accelerate the upgrading of China's petrochemical industry in terms of quality and efficiency, improve its international competitiveness, and expediently build strong petrochemical power.

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This study adopted the advanced international level as a benchmark to analyze the gap between China's petrochemical industry and that of the world's major petrochemical powers, focused on the high-quality development objectives of the industry, and presented the key tasks and countermeasures for the 14th Five-Year Plan and the vision for 2035 to provide theoretical references for the development of China's petrochemical industry.

2 New situations and challenges faced by China's petrochemical industry

2.1 Unprecedented global changes will accelerate the restructuring of the global industrial chain and pose new challenges to China's petrochemical industry.

Because of the impact of the COVID-19 pandemic, global industrial and supply chains are likely to be restructured. Some countries and multinational companies have begun to promote decentralized near-shore supply chains. Additionally, some downstream industrial chains of China's petrochemical industry face considerable pressure due to multiple issues such as foreign disinvestment and "desinicization." Domestic bulk petrochemical products face overcapacity. The average self-sufficiency rate of bulk petrochemical products is expected to exceed 90% by 2025, and approximately 70% of chemical products are at risk of overcapacity. With the up-gradation of the residents' consumption structure, the domestic market demand for high-end petrochemical products will increase. The potential market demand for petrochemical products in the Belt and Road countries will increase considerably, bringing new competitive advantages to China's petrochemical industry.

2.2 After technological innovation becomes the focus of competition among superpowers, it will be more challenging to introduce new technologies into China's petrochemical industry.

A new round of technological revolution and industrial reform involves reconstructing the world's innovation landscape and reshaping its global economic structure. This will profoundly change production methods and lifestyles. Technological innovation has become a major battlefield for strategic international games. With the intensified competition over technology, China's petrochemical industry has encountered restrictions in introducing foreign high-end technologies. Some disruptive technologies have gradually met practical conditions. For example, significant progress has been made in the direct conversion of natural gas to ethylene, which will impact the original technological deployment of China's petrochemical industry. However, some technical containment issues still exist in this industry. Domestic high-end petrochemical products are at risk of foreign extrusion and dumping. Moreover, it is increasingly imperative to strengthen the ability of original and independent innovation and realize self-reliance in developing high-level technologies.

2.3 With the rapid development of the new generation of information technologies, the petrochemical industry has entered a "smart" era.

With continuous breakthroughs in new-generation information technologies (e.g., big data, cloud computing, artificial intelligence (AI), 5th-generation mobile communication (5G) technology, and blockchain technology), the digital economy has developed tremendously. Competition has become oriented toward digitization, networking, and intelligence, constituting the leading force in driving innovation and transformation, and gradually reshaping the development model of petrochemical enterprises. Information and data have become core production factors in the petrochemical industry. Fully tapping data value, connecting procurement, production, and sales channels, building an intelligent modern circulation system, and realizing accurate operations based on big data analysis will create great economic value for the petrochemical industry. Undoubtedly, this new round of industrialization will reshape the value of the petrochemical industry.

2.4 China's economic development has entered a new stage; new fields and business formats are leading consumption patterns of petrochemical products.

Upon entering the new development stage, the top priority of China's economic development is to maximize the advantages of the domestic hyperscale market and promote the transformation and upgrading of the industrial structure. China has vigorously developed new industries, business formats, and models, built modern industrial and circulation systems with diversified development and multipolar support, and promoted the transformation of old growth drivers into new ones. The development of urban agglomeration and metropolitan areas; new infrastructure and urbanization construction, and construction of transportation, water conservancy, and other major projects; as well as key regional strategies (e.g., coordinated development of the Beijing–Tianjin–Hebei region, development of

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the Guangdong–Hong Kong–Macao Bay Area, regional integrated development of the Yangtze River Delta, and Hainan Free Trade Port), have become vital forces driving the new demand for petrochemical products. As China gradually becomes a high-income country, residents' growing living needs will promote the up-gradation of petrochemical product consumption. The rise of new business forms and economies (e.g., telemedicine, online education, and sharing platforms) will promote new consumption and production modes and expand the new consumption direction of petrochemical products.

2.5 The wave of green and low-carbon development is advancing steadily, and the peak of oil demand is imminent.

There is consensus in the international community that efforts should be made to promote green and low-carbon development to effectively cope with climate change and protect the ecological environment. Many countries accelerate energy reforms and transformations to improve energy resource utilization and reduce greenhouse gas and pollutant emissions. China has accelerated the development of hydrogen energy, bio-based liquid fuels, and new energy vehicles to achieve carbon peaks and neutralization. The growth rate of petroleum demand has slowed significantly, and petroleum demand may peak between 2035, and 2036, ahead of schedule. According to the International Energy Agency and Sinopec Economics & Development Research Institute Company Limited, China's oil demand will peak (7.14×10^8 t) by 2030.

2.6 With an increasing open macro market environment, competition in the petrochemical products market will intensify.

To accelerate the new "dual circulation" development pattern with the domestic cycle as the mainstay and the domestic and international cycles reinforcing each other, China must continuously accelerate the opening pace of the petrochemical product market. Consequently, domestic market competition exhibits a trend of diversified market players, and the profitability of China's petrochemical industry may remain low. International petrochemical companies, such as British Petroleum and BASF SE, have achieved comprehensive deployment in China's medium–high-end petrochemical products market, resulting in fierce competition. With the acceleration in the opening of free trade zones and the construction of free trade ports in the country, China's petrochemical industry will continue to encounter many novel opportunities and challenges.

3 Current development status and difficulties facing China's petrochemical industry

3.1 China's petrochemical industry has achieved outstanding results.

3.1.1 The industry has strong scale strength and a robust foundation for high-quality development.

After decades of development, China's petrochemical industry ranks among the best globally. In 2019, China ranked No. 2 among global petrochemical powers, and its production capacity and output of main products ranked among the top in the world (Table 1). There were 26 271 enterprises above the designated size in the petrochemical industry. Their total operating revenue reached 12.27 trillion CNY (accounting for 11.6% of China's total operating revenue), their profits amounted to 668.37 billion CNY (accounting for 10.8% of China's total profits), and their total assets amounted to 13.4 trillion CNY. The operating profit ratio for the entire industry is 5.45% [2]. The petrochemical industry has laid a robust foundation for high-quality development.

Table 1 Global ranking of Chinese major petrochemical product capacity in 2019.

Item	Capacity (1×10^4 t/a)	Proportion in the world (%)	Global ranking
Oil refining	87 475	17.5	2
Ethylene	2876	15.6	2
Synthetic resin	8691	28.9	1
Synthetic rubber	643	31.8	1
Synthetic fiber	6389	66.5	1

3.1.2 Industrial concentration is continuously increasing, and market participants have been diversified.

China's petrochemical industry has developed a large-scale, intensive, and base-oriented industrial layout. The scale of these enterprises has been increasing, and many oil refining projects with a production capacity of more than 10 million tons per annum (MTPA) and ethylene projects with a production capacity of more than 1 MTPA have been completed in succession. With the continuous concentration of production capacity in advantageous areas,

China has (1) established refining and petrochemical industry bases in the northeast and northwest of the country, which is the center of domestic crude oil resources; (2) created coastal petrochemical industry clusters in the Circum-Bohai Sea, Yangtze River Delta, and Pearl River Delta, which focus on imported crude oil and pay close attention to the market center; (3) formed the riverside petrochemical industry belt, which leverages crude oil pipelines along rivers to transport resources; and (4) built a modern coal chemical industry base that takes Northwest China with its rich coal resources as the center. From 2000 to 2019, the average processing capacity of China's refineries increased from 1.95×10^6 t/a to 4.56×10^6 t/a, and the number of refineries with a processing capacity of more than 10 MTPA increased from 4 to 28 [3]; the average scale of ethylene units increased from 2.2×10^5 t/a to 7×10^5 t/a (petroleum-based), and the number of enterprises with an ethylene capacity of more than 1 MTPA increased from 1 to 9 [4].

Because of the rapid implementation of private refining and petrochemical projects and the accelerated accession of large foreign oil refining and petrochemical companies in China in recent years, the petrochemical industry has formed a diversified development pattern with a broad range of companies and fierce competition. The China Petrochemical Corporation (Sinopec Group) and China National Petroleum Corporation (CNPC) are major market players. Various participants include state-owned enterprises, private enterprises, joint ventures, and foreign-funded enterprises. The market environment has become increasingly dynamic and open [2].

3.1.3 Technological innovation capability and technical level have significantly improved.

With the continuous improvement of independent innovation ability, China's petrochemical industry has built a relatively complete production technology system and developed the ability to leverage independent technologies to build many refineries with a production capacity of more than 10 MTPA, ethylene plants with a production capacity of more than 1 MTPA, and aromatic plants with a production capacity of more than 1MTPA. China has aggressively promoted new energy, new chemical materials, high-end special chemicals, and the construction of modern coal chemical innovation platforms and has strived to build a technological innovation system that integrates production, academia, research, and application. Thus far, China has made breakthroughs in many core technologies, realized the domestication of most catalysts and processing technologies, and acquired world-leading technologies and catalysts [5].

3.1.4 Product quality has been continuously improved, with commendable safety and environmental protection achievements.

China's petrochemical industry has continuously accelerated the up-gradation of oil quality and is recognized as the world leader in quality oil production. China's ordinary diesel standard is now stricter than that of developed countries and other regions, consistent with the China VI Emission Standard for gasoline and diesel vehicles officially implemented in 2019. China has actively improved the output of high value-added and high-end petrochemical products and increased the production capacity of special raw materials for synthetic resin, high-performance synthetic fiber products, special synthetic rubber, special chemicals, refined chemicals, and other products to substitute domestic products for imports, thereby meeting the development needs of relevant industries.

China's petrochemical industry has continuously enhanced green, low-carbon, and safe production and has continuously improved its impact on the ecological environment and people's lives. In terms of green and low-carbon development, China has accelerated the construction of green standardization systems, continuously reducing energy and material consumption, improving resource utilization, reducing pollutant emissions, and protecting the ecological environment. Overall, remarkable progress has been achieved in China. In terms of safe production, petrochemical enterprises consistently strengthen safety awareness, continuously improve safety management systems, strictly abide by safety responsibilities in production, and carefully safeguard residents' living environments.

3.1.5 With the accelerated integration of industrialization and informatization, China has made considerable strides in the demonstrative construction of intelligent factories.

Focusing on the two major themes of intelligent manufacturing and Internet Plus, China's petrochemical industry has been deepening supply-side structural reform, exploring the digital transformation of industries, and creating a new impetus for high-quality development by reducing costs and improving efficiency. By promoting the application of enterprise resource planning and other information technologies, China has built information platforms for operation and management, production and operation, information infrastructure, and operation and maintenance, covering all business fields of the entire industry. Moreover, it has realized the standardized management, intensive control, and integrated coordination of "human, assets, materials, supply, production, and marketing" and promoted management innovation and efficiency improvement to support the construction of competitive industrial advantages.

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China has accelerated the application of 5G, AI, the Internet of Things, big data, cloud computing, and other new-generation information technologies and has promoted the construction of intelligent petrochemical factories. SINOPEC Jiujiang Company, SINOPEC Zhenhai Refining & Chemical Company, Huizhou Petrochemical Co., Ltd. of the China National Offshore Oil Corporation, CNPC Changqing Company, and Wanhua Chemical Group Co., Ltd. were selected as the national intelligent manufacturing pilot demonstration enterprises. Constructing intelligent petrochemical factories has effectively promoted the reform of petrochemical enterprises' production and control modes and greatly improved safety in production, environmental protection, energy conservation and emissions reduction, cost reduction and efficiency enhancement, and the level of green and low-carbon development. For example, pilot demonstration enterprises have improved the advanced control utilization rate, automatic acquisition rate of production data, and labor productivity by more than 10% and established a new model for digital, automatic, intelligent production, and operation management, which gradually transforms local offline production optimization into integrated online production optimization and plays an obvious role in improving quality and efficiency, thus effectively promoting high-quality development.

3.2 Challenges faced by China's petrochemical industry in the process of pursuing high-quality development

3.2.1 Despite the large overall scale, the scale effect is not apparent.

The overall scale of China's petrochemical industry is second only to the United States and ranks at the forefront of the world's petrochemical industry. However, this did not produce a corresponding scale effect. China's petrochemical industry still lags behind other petrochemical powers, such as the United States and Germany, regarding technical and economic levels, profitability, and competitive strength. It is generally at the medium to the low end of the global industrial and value chains. The main reasons for this are as follows. First, owing to the scattered business layout and small average scale, it is challenging to cultivate leading enterprises that possess international competitiveness and comprehensively optimize the utilization of resources, thereby affecting the overall improvement of industrial competitiveness. Second, several enterprises have backward technology and capacity. For example, in 2019, 67 oil refineries had a processing capacity of less than 2×10^6 t/a, and 54 oil refineries had a processing capacity of less than 1×10^6 t/a [6].

3.2.2 The contradiction of structural shortage in the industry is prominent.

Chinese petrochemical enterprises have an excess refinery capacity. Bulk petrochemical products account for a large proportion, whereas the high-end and high value-added products account for a small proportion, resulting in the contradiction of structural shortages in the industry from which signs of vicious homogenized competition have emerged. On the one hand, in 2019, China's oil refining capacity reached 8.7×10^8 t, crude oil processing capacity was 6.5×10^8 t, and the operating rate of 74% was significantly lower than the world average level (83%). On the other hand, the total import and export volume of China's petrochemical industry amounted to 722.21 billion USD, with a trade deficit of 268.32 billion USD. China remains highly dependent on the imports of high-density polyethylene, polycarbonate, engineering plastics, electronic chemicals, high-performance fibers, and high-end membrane materials [6].

3.2.3 The unbalanced development among regions must be addressed.

The capacity distribution of China's petrochemical industry is not well coordinated and must rely on north-to-south and west-to-east oil transfers. The optimal allocation level of resources in a region must be further improved. With the disorderly development of refinery capacity in some areas, China has built several inefficient and low-level non-scale refinery capacities. However, the distribution of the modern coal chemical industry lacks guidance; some projects are located in areas with inappropriate external conditions, such as inappropriate environmental capacity and water resources; others are situated in environmentally sensitive areas that are close to centralized water sources or key water and soil loss prevention and protection areas, which carry environmental risks [7].

3.2.4 Disparity remains in terms of enterprise profitability and competitiveness.

China's petrochemical industry still lags behind its counterparts in advanced countries: return on investment, total factor labor productivity, profitability, and comprehensive competitiveness. For example, in the Global 500 companies ranking in 2020, most multinational petrochemical companies had a high asset profit margin of 4%–10%, whereas many Chinese petrochemical companies were approximately 1%, and some even lost money.

3.2.5 The lack of independent innovation ability restricts high-quality development.

Compared with other petrochemical countries, China's petrochemical industry still lacks independent innovation

ability, which has become a bottleneck restricting its high-quality development. This is reflected in the following aspects. First, there is insufficient investment in technology. The R&D investment of large international petrochemical companies accounted for approximately 3% of sales revenue, while that of Chinese petrochemical enterprises accounted for only approximately 1%. Second, there is poor original innovation ability. China's petrochemical industry lacks original, new, and high-end petrochemical product technology. Third, the overall efficiency of the innovation system is not high, and the technological R&D mechanism cannot fully match the requirements for high-quality development in the petrochemical industry [5].

3.2.6 The deep integration of industrialization and informatization is restricted by various factors.

China's petrochemical industry has adopted enterprise pilot construction and project pilot application methods to promote intellectualization. There is insufficient systematic theoretical systems research, and the construction of related systems, such as industrial Internet standards and industrial control security protection, still lags behind those of other countries. In the smart development process, imported engineering design, embedded software, and automatic control systems have dominant advantages. However, many problems remain, such as a lack of ability to develop domestic software, a low standardization level, and poor commercialization and popularization. Given that most software used for industrial design, process simulation, production process control and optimization, and industrial applications comes from abroad, there are potential technical containment problems and systematic risks. The core equipment required for intelligent petrochemical production is still controlled by other countries; thus, China remains highly reliant on the import of key equipment, core components, and other hardware. It takes time to achieve a large-scale supply of domestic hardware [8].

3.2.7 The market operation order needs to be further standardized.

Despite China's significant surplus in refinery capacity, some regions and enterprises are still actively building large oil refineries, and slow progress has been made in eliminating oil refineries with a backward refinery capacity. The primary reason for this is that the refined oil market lacks standardization and supervision, and high profits can be obtained by evading the consumption tax. Bare oil without consumption tax enters the refined oil market at a low price and undermines fair competition and market order, causing the phenomenon of "bad money driving out the good." In terms of supervision mode, too much reliance on "strengthening financial supervision by invoice management" provides an opportunity for some merchants to avoid invoices and change their face value to evade consumption tax. In terms of regulatory coordination, special campaign-like law enforcement of taxes, public security, customs, and other fields has achieved certain results in the short term. However, this type of enforcement lacks legal bases in the long term.

3.2.8 Green and low-carbon safety production and environmental protection have exerted increasing pressure.

Pollutant emissions from the petrochemical industry have significantly exceeded the advanced international level, such as wastewater, waste gas, and solid waste [9]. The modern coal chemical industry has some prominent issues, such as large emissions of CO_2, pollutants, and high-salt wastewater that exceed the prescribed limits in China. Under the major background of pursuing carbon peak and carbon neutralization, with the continuous implementation of the Blue Sky Defending War policy and pollution prevention and control, China plans to implement some new, more stringent environmental protection policies and standards that will restrict CO_2 emissions and energy consumption, and exert greater environmental protection pressure on the petrochemical industry. Chinese petrochemical enterprises continue to experience such accidents. Particularly, some small local chemical plants experienced several major or serious accidents, thus necessitating further emphasis on safe production in the petrochemical industry [10].

4 General ideas, objectives, and tasks for high-quality development of China's petrochemical industry

4.1 General ideas

Upholding the principle of "being value-oriented, promoting structural optimization, emphasizing quality and efficiency, innovation as a driving force, intelligent improvement, reform and opening up, international cooperation, intrinsic safety, and green development," China's petrochemical industry should adopt increasing supply-side structural reform as the primary goal, strive to enhance endogenous development power, and strive to optimize and adjust the structure to improve quality, increase efficiency and upgrading, enhance innovation ability, and reshape dual circulation. China's petrochemical industry should accelerate the implementation of green molecular

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manufacturing and pay more attention to safety protocols during production and environmental protection. Moreover, it should vigorously promote international cooperation, actively carry out digital transformation, continuously improve total factor labor productivity, and comprehensively improve the industry's overall competitiveness. Meanwhile, the petrochemical industry should strive to create some famous brands with international influence; actively cultivate a batch of world-class petrochemical companies, high-level petrochemical parks, and industry clusters with strong international competitiveness; and vigorously promote changes in quality, efficiency, and growth drivers.

4.2 Main objectives

Based on a comprehensive analysis of the new opportunities and challenges faced by China's petrochemical industry and an objective evaluation of the current development conditions, it is expected that after 15 years of effort, the industry will transform scale- and speed-oriented development modes into quality- and efficiency-oriented development modes. The factor-driven force of development will transform into an innovation-driven driving force. The development structure will shift its focus from capacity expansion to strengthening existing operations and optimizing incremental assets in an all-around manner. Relying on green molecular manufacturing: the petrochemical industry will lead to high-quality development in China's manufacturing industry, move toward the medium-high end of global industrial and value chains, and ensure that China continues to rank at the forefront of the world's powerful petrochemical countries.

In Stage 1 (2021–2025), China's petrochemical industry will achieve high-quality development, and its oil refining industry will reach an advanced international level. China will steadily improve the quality and efficiency of its petrochemical industry, significantly enhance its technological innovation ability, further coordinate and optimize its distribution structure, continuously improve its effective supply capacity, achieve exceptional results in digital transformation, make breakthroughs in green molecular manufacturing, consciously pursue safe production and environmental protection, constantly improve its international operational level, and significantly strengthen its international competitiveness. Additionally, China will form three to four large integrated refining and petrochemical industry clusters with reasonable distribution and strong international competitiveness and establish five to six world-class large petrochemical enterprises with strong international competitiveness.

In Stage 2 (2026–2035), with consistent efforts, the petrochemical industry will achieve high-quality development in an all-around manner, and China will fully establish itself as a leading global petrochemical power. The petrochemical industry will achieve a robust structural layout, good quality and efficiency, strong innovation ability, high production efficiency, safe production, excellent environmental protection, good international cooperation, and strong competitiveness. Further, it will realize green molecular manufacturing completely, move toward the medium to the high end of the global industrial and value chains, better meet the growing needs of residents for a better life, and form five to six world-class large-scale integrated refining and petrochemical industry clusters, cultivate several top-notch large petrochemical enterprises, and deliver China's overarching goal of building a socialist modern power.

4.3 Key tasks

4.3.1 Pursuing high-level self-reliance and self-improvement in petrochemical technology development

China should accelerate its efforts to tackle key core technologies and improve the stability and competitiveness of the industrial chain, give full play to the advantages of the new national system under the condition of a socialist market economy, concentrate on building advantageous scientific research forces, and strive to overcome technical containment issues that undermine the safety of industrial chains [11]. Focusing on new energy, high-performance resin, special synthetic rubber, high-performance fiber, medical materials, and other high-end petrochemical products, China should also increase investment in technological research and strengthen the independent and controllable ability of the industrial and supply chains. Additionally, China should focus on the key issues in the future development of the petrochemical industry, give full play to the advantages of national strategic technological forces, strengthen basic research on cutting-edge technical directions (e.g., new catalytic materials, molecular oil refining, molecular chemical engineering, and process strengthening), and identify and seize the commanding heights of future development.

4.3.2 Strengthening and optimizing the petrochemical industry

China should accelerate structural adjustment, transformation, and up-gradation; implement supply-side structural reform in the petrochemical industry; develop a scientific plan for new petrochemical production capacity; develop

base-oriented, intensive, and large-scale advanced production capacity; strictly control new refinery capacity; eliminate backward and inefficient production capacity, and accelerate the construction of world-class large-scale integrated refining and petrochemical bases. Focusing on the major strategic needs of the national high-end manufacturing industry, China should realize the domestication of high-end petrochemical products such as special engineering plastics, functional materials, and high-purity electronic chemicals; carry out the construction of industrial upgrading projects that highlight the quality upgrading of refined oil products and high-end chemical products; and make up for the shortcomings of the industrial chain to move toward the medium to the high end of industrial chains.

4.3 3 Promoting green and low-carbon development

China should actively implement clean production technology transformation; promote advanced energy-saving, low-carbon, water-saving, and emission-reduction technologies in an all-around manner; accelerate the application of clean energy resources such as hydrogen, solar, and wind energy; strengthen the research and application of energy storage technologies, especially chemical energy storage technology, and promote the comprehensive green transformation of the petrochemical industry. To address the major challenge of terminal energy re-electrification, China should optimize and adjust the energy consumption structure of the petrochemical industry, strengthen energy conservation and emission reduction, strive to develop electric energy substitution, and actively carry out the construction of carbon capture, utilization, and storage (CCUS) demonstration projects orderly. Meanwhile, China should thoroughly study the implementation path of carbon peaking and neutralization in the petrochemical industry, actively deploy R&D and demonstrative applications of CCUS chemical conversion and utilization technologies, and accelerate the deployment and implementation of technologies and the roadmap for carbon peaking and neutralization in the petrochemical industry.

4.3.4 Improving intrinsic safety levels

China should strengthen the design concept of intrinsic safety, promote intrinsic safety technology, and leverage modern information technology to improve the intrinsic safety level of petrochemical enterprises in an all-around manner. They should strictly abide by the basic bottom line of safety production, improve safety regulations and standards in the petrochemical industry, and establish a unified safety management system. The country should implement an access permit system, improve access standards, coordinate the site selection and layout planning of petrochemical projects throughout the country, establish a linkage mechanism for land use approval, and take various measures (e.g., the comprehensive on-site transformation of petrochemical enterprises, relocation of enterprises, or construction of surrounding residential areas) to solve the issue of “petrochemical factories in urban areas.”

4.3.5 Accelerating digital transformation

According to the national plan, China should develop a good top-level design, adopt a technical route of parallel promotion and integrated development, and fully carry out the construction of intelligent petrochemical factories [11]. Additionally, it should also promote the digitization of engineering design and realize the full lifecycle digital management of factory design, engineering construction, and production operations; promote intelligent supply chain management; align the optimization and coordination of enterprises’ internal supply chain with the entire industry’s supply chain; promote intelligent production operations, and realize the vertical integration of internal information. Furthermore, China should accelerate the domestication process of engineering design software and realize the full autonomy of production control systems and engineering design software in the petrochemical industry, promote knowledge management and intelligent business decision-making, and form a multidisciplinary and vertically integrated management and control system.

4.3.6 Expanding the refining and petrochemical industry layout in Belt and Road countries

China’s petrochemical industry enjoys unique advantages in terms of petrochemical plant design, production techniques, equipment manufacturing, engineering construction, and talent teams. It can provide one-stop services to refineries with a processing capacity of more than 10 MTPA, ethylene plants with a production capacity of more than 1 MTPA, and aromatic plants with a production capacity of more than 1 MTPA, thereby covering technology licensing, process package design, start-up, and commissioning. China should leverage relevant service advantages to expand the trade of petrochemical products with countries along the Belt and Road, actively promote the construction of refining and petrochemical projects along the Belt and Road, expand business distribution in overseas petrochemical industries, and demonstrate the globalization achievements of China’s petrochemical industry.

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5 Countermeasures and suggestions

5.1 Strengthening top-level design and vigorously guiding industrial upgrading of quality and efficiency

China should focus on improving quality and efficiency, make a scientific development plan for the petrochemical industry, and establish an evaluation system and assessment mechanism to safeguard high-quality development and guide industrial optimization and upgrading. China should also implement nationwide arrangements, make overall plans for developing the petrochemical industry, establish a high-quality development evaluation system for the petrochemical industry, and improve the assessment mechanism that focuses on developing quality and economic benefits.

5.2 Establishing a market-oriented production capacity regulation mechanism and accelerating the transformation of old energy into new energy

China should establish a market-oriented refining and petrochemical capacity control mechanism, gradually overcome the issue of overcapacity, accelerate the transformation from old growth drivers to new ones, and prevent the risk of newly added production capacity. China should also improve its industrial access and licensing requirements, establish a market-oriented exit mechanism, establish a de-capacity market transaction mechanism, safeguard the exit and transformation of petrochemical enterprises, and establish a production capacity early warning mechanism for the entire industrial chain.

5.3 Reinforcing the support for technological innovation and enhancing the core competitiveness of the industry

Combined with further deepening the reform of technology systems and mechanisms, China should accelerate the construction of a market-oriented technological innovation system in the petrochemical industry, which considers enterprises as the main market players and integrates production, academia, research, and application. The country should improve the mechanism of tackling core technologies that reflect industry characteristics, constantly support technological innovation to improve the quality and efficiency of the petrochemical industry and strengthen the driving force of technological innovation in promoting high-quality development of the petrochemical industry. Furthermore, China should give full play to the main role of enterprises in boosting technological innovation in the petrochemical industry, establish a common technical service alliance, optimize the investment direction of financial and technology funds, explore venture capital modes, and provide vigorous support for scientific research projects.

5.4 Optimizing the business environment and building a fair market competition environment

China should establish a fairer, standardized, and more open petrochemical market environment than the present one, give full play to the decisive role of the market in resource allocation, fully leverage the macro-control role of government institutions, and maintain the benign competition and healthy development of the petrochemical industry. China should implement a unified industrial investment, market, and trade access system and change the refined oil consumption tax from a central tax to a central-local shared tax. It should also strengthen the punishment for evasion of refined oil consumption tax in accordance with regulations to build a fair and transparent competition environment.

5.5 Improving environmental protection policies and promoting the safe and green development of the petrochemical industry

While streamlining administration and delegating powers and project approval rights, China should pay attention to on-processing and post-event supervision, particularly the supervision and enforcement of the implementation of safety production and environmental protection policies to help the petrochemical industry continuously enhance environmental protection and realize sustainable development. China should strengthen its position of environmental assessment in regional industrial planning, conduct safety, and environmental supervision regularly, and establish a market-oriented mechanism for ecological protection. Governments at all levels should increase the funding guarantee for the safety and environmental supervision departments.

5.6 Deepening the Belt and Road Initiative and strengthening industrial and international cooperation

China should continuously carry out and deepen Belt and Road construction in the post-pandemic era and promote the global layout of its petrochemical industry chain to ensure national energy security comprehensively. China

should further expand the cooperation scope of the Belt and Road, encourage Belt and Road countries to establish an energy cooperation community, strengthen research on international risk judgment and prevention policies, and support advantageous enterprises to make investments and jointly build refining and petrochemical projects in the Belt and Road countries.

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