

Status and Prospects of China's Petroleum and Petrochemical Industry under the Dual Carbon Targets

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Abstract: The article delves into the current landscape and prospects of China's petroleum and petrochemical sector amidst the dual-carbon mandate. This sector has garnered considerable attention ever since the Chinese government set forth the ambitious objectives of attaining peak carbon emissions by 2030 and achieving carbon neutrality by 2060. Despite its pivotal role in the nation's economy, the petroleum and petrochemical industry continues to grapple with elevated carbon emissions. Consequently, imperative actions are warranted to curtail these emissions, leveraging advancements in technology and the adoption of clean energy alternatives. Presented within this article is a transformative trajectory for the petrochemical industry in alignment with the dual-carbon agenda. This trajectory encompasses the phasing out of obsolete production capacities, recalibrating the energy framework, and fortifying avenues for technological innovation. Furthermore, the article elucidates on the prospective evolution of China's petrochemical domain under the ambit of the dual-carbon directive. Emphasizing its instrumental role in facilitating the energy transition, achieving heightened equilibrium between supply and demand dynamics, and propelling forward technological innovation and industrial refinement.

Keywords: Double Carbon Target; Petroleum and Petrochemical; Energy Transition.

1. Introduction

China has set forth ambitious objectives to bolster its nationally determined contributions and implement more robust policies and measures aimed at reaching peak carbon emissions by 2030, followed by a concerted effort towards carbon neutrality by 2060. Consequently, the landscape of research and development towards a carbon-neutral trajectory in China is swiftly evolving, carrying substantial implications for future industrial trends. Among the nation's six major energy-consuming sectors, the petrochemical industry has emerged as a focal point within this discourse.

Statistics underscore the significant carbon footprint associated with the petrochemical sector, attributing approximately 13% of China's total carbon emissions to its production processes and 17% of carbon emissions within the industrial domain. Moreover, the utilization of fossil feedstocks in petrochemical production engenders carbon emissions across the end-consumption spectrum. While not the primary contributor to overall carbon emissions, the petrochemical industry surpasses the industrial sector's average emission intensity, thus confronting the imperative to reduce carbon emissions in tandem with national mandates on total emissions and intensity control.

To navigate this challenge, the petrochemical industry must pivot towards a paradigm of technological innovation, embracing low-carbon production methodologies, integrating clean energy solutions, and enhancing energy efficiency measures. Concurrently, governmental intervention in the form of more stringent policies and incentivization mechanisms is essential to propel the industry towards the trajectory of carbon neutrality. Such concerted efforts are pivotal in realizing the collective aspiration of peaking carbon emissions by 2030 and steering towards carbon neutrality by 2060.

2. Status of China's Petroleum and Petrochemical Industry under the Dual Carbon Targets

China's petrochemical industry stands as a cornerstone of the national economy, characterized by its expansive product portfolio and its capital- and technology-intensive nature, holding profound industrial significance. The intricate and multifaceted production and processing processes within this sector span from crude oil extraction to the refinement of chemical raw materials and the manufacturing of diverse chemical products. Guided by robust governmental policies, China's petrochemical industry has experienced remarkable strides, witnessing a sustained escalation in the output of key products. From 2015 to 2023, the nation's aggregate oil and gas production exhibited a steadfast upward trajectory, surpassing the 390 million-tonne mark (in oil equivalent) by 2023, maintaining an impressive annual growth rate of 10 million tonnes for seven consecutive years. By the culmination of 2022, the landscape of China's petrochemical sector featured a formidable assembly of enterprises, with 25,974 entities operating at a certain scale. Reflecting the sector's vigor, total assets soared to an impressive tally of 1,640.327 billion yuan, with sales revenue and industry profit reaching 1,693.196 billion yuan and 1,416.79 billion yuan respectively. In recent years, the investment landscape of China's petroleum and petrochemical domain has demonstrated a pattern of fluctuating growth, culminating in a historic pinnacle of 2,618.66 billion yuan in 2022. Remarkably, a substantial portion of this investment, constituting 80%, was earmarked for petrochemical feedstock manufacturing, underscoring its pivotal role. Additionally, allocations of 10.7% and 9.66% were respectively designated for investment in oil and gas extraction and in the processing of oil, coal, and other fuel industries, affirming the diversified nature of the sector's investment focus.

China's petroleum and chemical sectors presently hold the esteemed positions of being the second largest globally, with the chemical industry reigning supreme. Remarkably, the sales of chemical products in China command approximately 44% of the worldwide chemical market share, a figure equivalent to the combined markets of Europe, the United States, and Japan. Notwithstanding the industry's colossal scale, there exists a discernible gap in meeting the burgeoning demand for petrochemical and chemical products within China's economy and society. As of 2021, China has attained self-sufficiency rates of 61.5% for ethylene and 61.6% for paraxylene equivalents. To fortify the resilience of the domestic industrial chain, it becomes imperative to bolster the supply capacity of essential bulk products and augment the production scale of select items. The burgeoning demand for chemicals in novel sectors such as new energy, chemical synthetic materials, their composite derivatives, functional chemicals, and life science products necessitates a commensurate expansion in chemical production capacity. Furthermore, as industrial structural upgrades ensue and stringent environmental protection standards come into play, there looms the prospect of heightened energy consumption. Such dynamics may, in turn, contribute to an uptick in the industry's carbon emissions. In a forward-looking initiative, the Petrochemical Federation internally scrutinized the industry's carbon emissions trajectory over the past decade and prognosticated projections for the forthcoming 15 years, underscoring the critical need for proactive mitigation strategies. Amidst this milieu, it is paramount to recognize that attaining the 'dual carbon' target and fostering green [1], low-carbon development necessitate not a deceleration or cessation of progress, but rather an elevation towards superior, swifter, and higher-quality development concomitant with a reduction in carbon emissions. Development, undeniably, remains the bedrock and linchpin for addressing all challenges confronting China.

3. Transformation Path and Development Prospects of China's Petroleum and Petrochemical Industries under the Dual Carbon Targets

3.1. Transformation Path

To enhance energy efficiency and curb pollution, a strategic imperative lies in the elimination of antiquated and energy-intensive production processes and capacities. Within the petrochemical sphere, relentless endeavors must be directed towards the continual reduction of energy consumption intensity. Specifically, the oil refining domain ought to exercise stringent control over the magnitude of crude oil processing while concurrently optimizing refining procedures, recalibrating product compositions, and augmenting the availability of clean and low-carbon fuels. A pivotal aspect of this endeavor involves orchestrating a seamless transition towards electrification of domestic transport and the ensuing peak in refined oil product consumption. This entails judiciously adjusting refined oil supply to ensure a harmonious energy transition within the transportation sector. Simultaneously, proactive measures shall be undertaken to catalyze the conversion of oil resources into an augmented production yield of petrochemical raw materials, such as chemical light oil, thereby ensuring a robust

supply of critical petrochemical products like ethylene and aromatics within China. Central to this strategic agenda is the prioritization of obsolescence of backward production capacities. Leveraging their resource endowments and technological prowess, oil refining enterprises stand poised to spearhead this transformational journey, bolstered by supportive national policies. By repurposing obsolete units and pivoting towards the production of liquid biofuels such as bio-jet fuel and biodiesel, these enterprises are poised to significantly elevate the proportion of low-carbon fuels supplied to the transportation sector, thus heralding a greener, more sustainable future.

The overarching objective is to refine the structure of industrial energy utilization while gradually diminishing reliance on coal. This strategic endeavor hinges upon the steadfast promotion of transformative initiatives within the industrial landscape, including coal-to-gas, coal-to-electricity, and coal-to-hydrogen conversion projects. The overarching aim is to curtail the prevalence of coal-powered energy within industrial operations, thereby exerting control over fossil fuel consumption and carbon emissions, while simultaneously diminishing the intensity of carbon emissions. Anticipating the horizon of 2030, the aspiration is to confine coal consumption within petroleum and petrochemical enterprises to no more than one-third of the current total energy consumption. To realize this ambitious objective, a multifaceted approach is indispensable. This entails delving deeper into the realm of clean and efficient coal utilization, augmenting the proportion of low-carbon and zero-carbon energy sources, and enhancing the electrification of industrial energy infrastructure. Furthermore, a gradual escalation in the utilization of natural gas and non-fossil energy resources within enterprise energy consumption profiles is imperative. This concerted endeavor holds the promise of effectuating substantial reductions in carbon emissions stemming from production and processing activities, thereby fostering a greener and more sustainable industrial landscape.

The overarching goal is to foster synergistic advancement between the refining and sales business and the burgeoning hydrogen energy industry chain. Central to this endeavor is the strategic imperative of catering to the discernible demand in key urban centers, while concurrently expanding the high-end market for both domestic and international hydrogen energy applications. Special attention is warranted towards the cultivation of pioneering technologies for hydrogen production, notably those harnessing wind power and nuclear energy.

In developed regions, there exists a pressing need to actively pursue commercial ventures pertaining to hydrogen storage and transportation in collaboration with strategic partners and key stakeholders [2]. This collaborative approach is pivotal for unlocking the full potential of hydrogen energy deployment and fostering a sustainable transition towards cleaner and low-carbon energy paradigms.

3.2. Development Prospects

In the landscape of peak carbon and carbon neutrality imperatives, the petrochemical industry stands poised for transformative shifts in both demand dynamics and supply paradigms. The exponential growth of the new energy sector, encompassing photovoltaics, wind power, and power batteries, precipitates a burgeoning demand for chemical products spanning both traditional stalwarts and innovative materials.

Illustratively, the burgeoning demand for photovoltaic glass has engendered a commensurate surge in the utilization of soda ash, a trend projected to perpetuate its rapid ascent. Likewise, the escalating requisites for epoxy resins tailored for wind turbine blades and curing agents for wind power coatings have opened new vistas of opportunity. Notably, Wanhua Chemistry has emerged as a global trailblazer in the domain of curing agents for wind power coatings, underscoring the industry's adaptive prowess.

Moreover, the escalating demand for lithium iron phosphate materials in power batteries indirectly fuels requisites for industrial-grade monoammonium phosphate and phosphoric acid, catalyzing advancements within the phosphorus chemical realm.

On the supply front, advancements in product technology and process routes herald the advent of heightened production of high-quality, low-carbon chemical offerings. Notably, refining and chemical enterprises are at the vanguard of optimizing resource allocation while championing innovative approaches such as 'reducing oil and increasing chemicals' to tackle China's refining overcapacity conundrum and address shortages in ethylene and aromatics raw materials.

Similarly, petrochemical enterprises pivot towards offering environmentally friendly thermoplastic elastomers as a superior alternative to conventional rubber processing, thereby mitigating energy consumption and pollution concerns while fostering sustainable industrial practices.

In the realm of the chemical industry, carbon dioxide transcends its conventional depiction as a malevolent byproduct, emerging instead as a potent resource ripe for exploitation. Presently, chemical juggernauts and multinational entities worldwide are at the vanguard of pioneering technologies aimed at harnessing the full potential of carbon dioxide. Remarkable strides have been witnessed across various fronts, encompassing both the physical utilization (e.g., pharmaceuticals, beverages, carbon dioxide-fueled oil, etc.) and chemical utilization (e.g., methanol production, polyols, degradable plastics, etc.) realms. Additionally, groundbreaking progress is underway in the realm of bio-utilization of carbon dioxide.

Noteworthy achievements abound, including the Tianjin Institute of Industrial Biotechnology of the Chinese Academy of Sciences' landmark breakthrough in starch production from CO₂. Furthermore, Wei Fei's team at Tsinghua University has made notable headway in the production of green aviation kerosene from CO₂. Japan, too, has recently achieved a milestone in the synthesis of synthetic styrene-butadiene rubber utilizing carbon dioxide. In the backdrop of burgeoning technological prowess, competitive advantage in the future hinges significantly on technological acumen.

Guided by the imperatives of the dual-carbon target, the imperative of constructing a green and low-carbon production ecosystem characterized by high technological prowess, minimal resource consumption, and negligible environmental impact has assumed paramount importance for industry advancement. Moving forward, critical technologies such as energy-saving and carbon-reduction methodologies, novel catalytic approaches, process optimization techniques, high-efficiency separation methodologies, advanced control and information technologies, as well as carbon capture, utilization, and sequestration techniques, will be accentuated and leveraged.

Moreover, emphasis will be placed on clean and efficient coal utilization technologies, new energy-saving modalities,

renewable energy integration, hydrogen technologies, energy storage solutions, and smart grid infrastructures [3]. Additionally, the development of high-end functional and intelligent materials, degradable plastics technologies, and recycling methodologies for waste chemicals will receive heightened focus and investment.

Breakthroughs in these pivotal domains are poised to propel scientific and technological innovation within the petrochemical sector, facilitating comprehensive industry upgrading. Throughout this epochal scientific and technological revolution and industrial ascent, a cohort of world-leading petrochemical enterprises is poised to emerge, emblematic of the sector's transformative trajectory towards sustainability and innovation.

4. Conclusion

The oil and petrochemical sector are confronted with the imperative of eliminating outdated production capacities characterized by high energy consumption and low efficiency, while simultaneously recalibrating the traditional energy matrix to foster emission reduction initiatives. This necessitates a concerted focus on intensifying research, development, and implementation efforts surrounding green and low-carbon technologies. Such endeavors hold promise not only in ameliorating carbon emission intensity and enhancing resource utilization efficiency but also in navigating the challenges posed by technological obsolescence and cost pressures.

In the epoch of carbon peak, the oil and petrochemical industry assumes a dual mantle. On one hand, its traditional energy provisioning remains indispensable, serving as the linchpin for ensuring energy security. Simultaneously, the industry must embrace an active role in spearheading advancements within nascent energy domains, particularly in realms like hydrogen energy and other emerging fields. As energy dynamics undergo transformation, the petroleum and petrochemical landscape stands poised at the cusp of novel market opportunities and challenges.

Embracing the imperative of Carbon Dafeng Carbon Neutral, the industry is primed to catalyze technological innovation and industrial upgradation. This entails a concerted upsurge in research and development endeavors pertaining to green and low-carbon technologies, thereby steering the sector towards a heightened state of equilibrium between supply and demand dynamics. Concurrently, the Carbon Neutral paradigm is set to propel the industry towards a novel era of coupling with other sectors, fostering novel modes of industrial integration and forging fresh pathways for green and low-carbon development.

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