

Confidential

Independent Market Research on China Benzene-based Chemicals and Energy Industries

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Signature: Wesley Xiang

Date: 12 December 2023

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Agenda

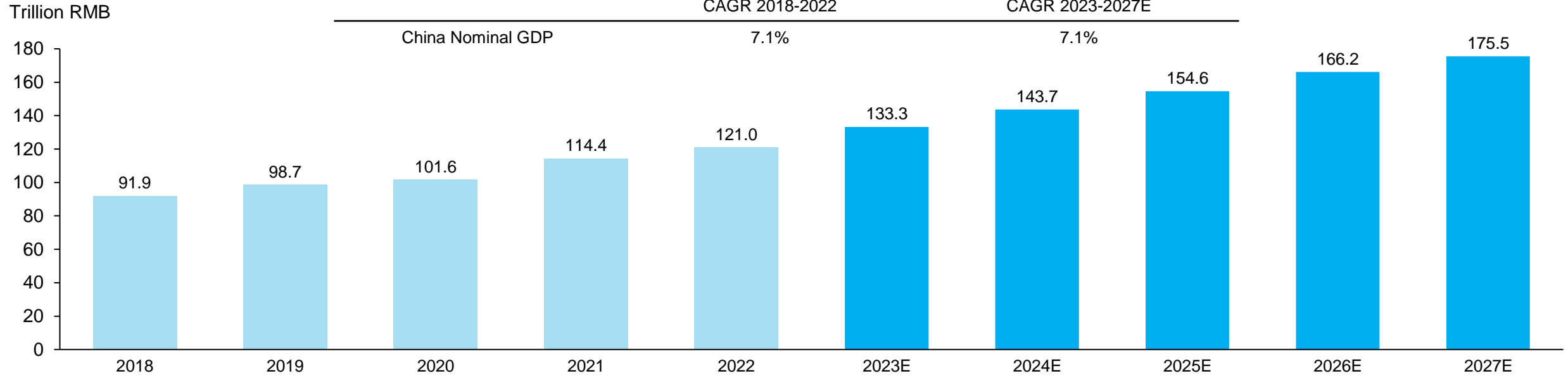
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- 2 Overview of Refined Chemicals Derived from Coal
Chemical Coking Market in China
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Overview of Macro Economic Environment

Nominal GDP

Nominal GDP (China), 2018-2027E



- Thanks to a series of economic stimulus policies adopted by the Chinese government, including the “Four Trillion Plan” (“四万亿计划”) and the “Ten Industry Revitalization Plan” (“十大产业振兴规划”), China’s GDP has maintained a relatively rapid growth in the past few years. The nominal GDP increased from RMB91.9 trillion in 2018 to RMB121 trillion in 2022 at a CAGR of approximately 7.1%. The outbreak of COVID-19 in January 2020 has temporarily impacted China’s overall economy. The GDP in the first quarter of 2020 had a decrease of 6.8% compared to last year. However, with the great efforts made across the country, the Chinese government’s anti-epidemic measures were quickly implemented and the epidemic was effectively controlled within a short period of time. China’s economic growth has turned from negative to positive since the second quarter of 2020. Driven by a series of proactive fiscal and monetary policies by the government, the economy has gradually returned to normal, making it one of the few countries in the world to achieve positive economic growth in 2020. In the post COVID-19 era, China will further enhance its innovation capabilities, create a large domestic market, promote higher levels of reform and opening up, and achieve high-quality economic growth. China’s nominal GDP is expected to climb to RMB175.5 trillion in 2027, representing a CAGR of approximately 7.1% from 2023.

Overview of Macro Economic Environment

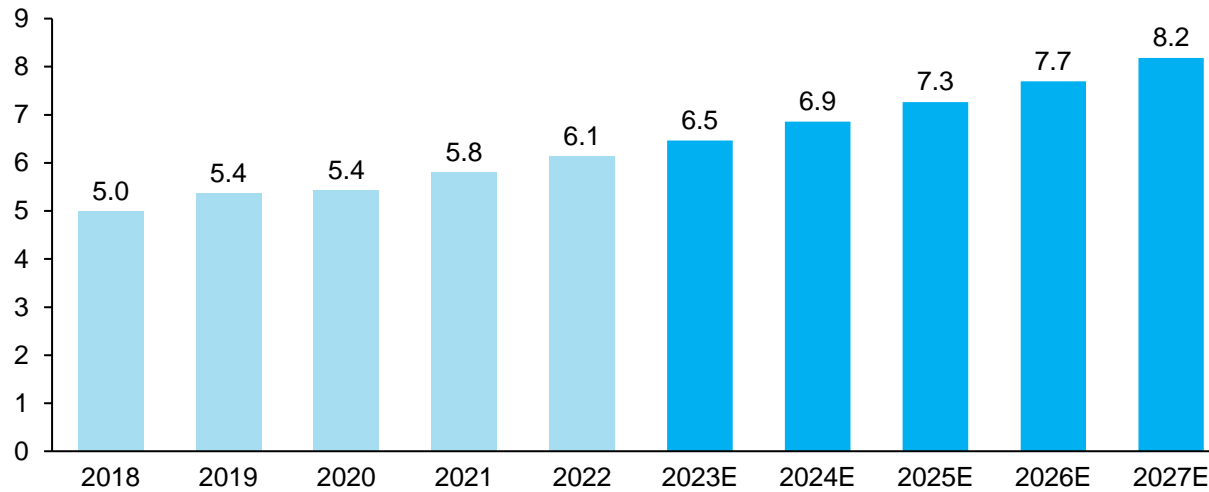
Nominal GDP

Nominal GDP (Henan Province), 2018-2027E

CAGR 2018-2022: 5.3%
CAGR 2023E-2027E: 6.0%

Henan Nominal GDP

Trillion RMB

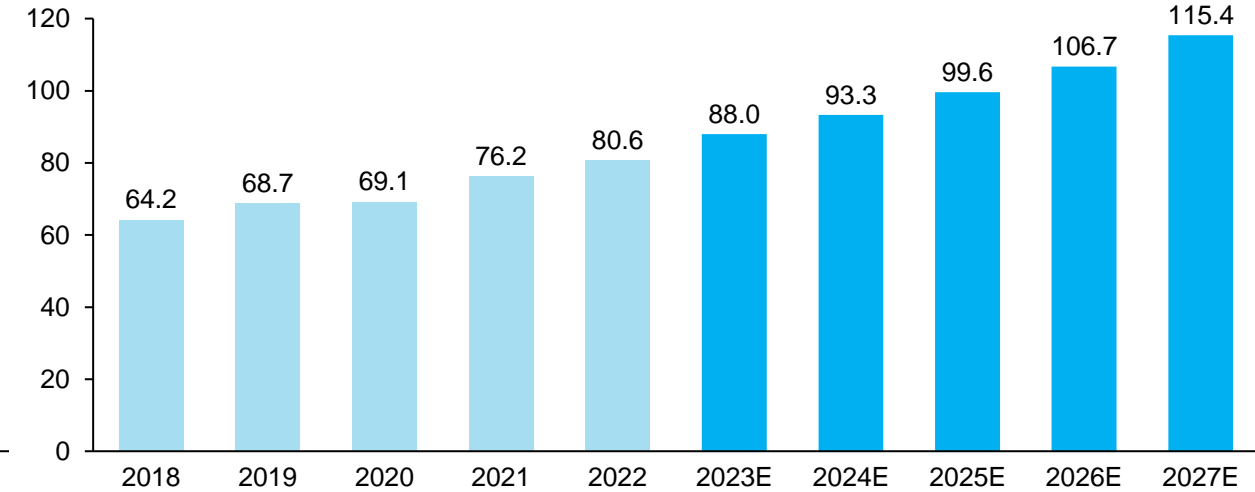


Nominal GDP (Jiyuan), 2018-2027E

CAGR 2018-2022: 5.9%
CAGR 2023E-2027E: 7.0%

Jiyuan Nominal GDP

Billion RMB

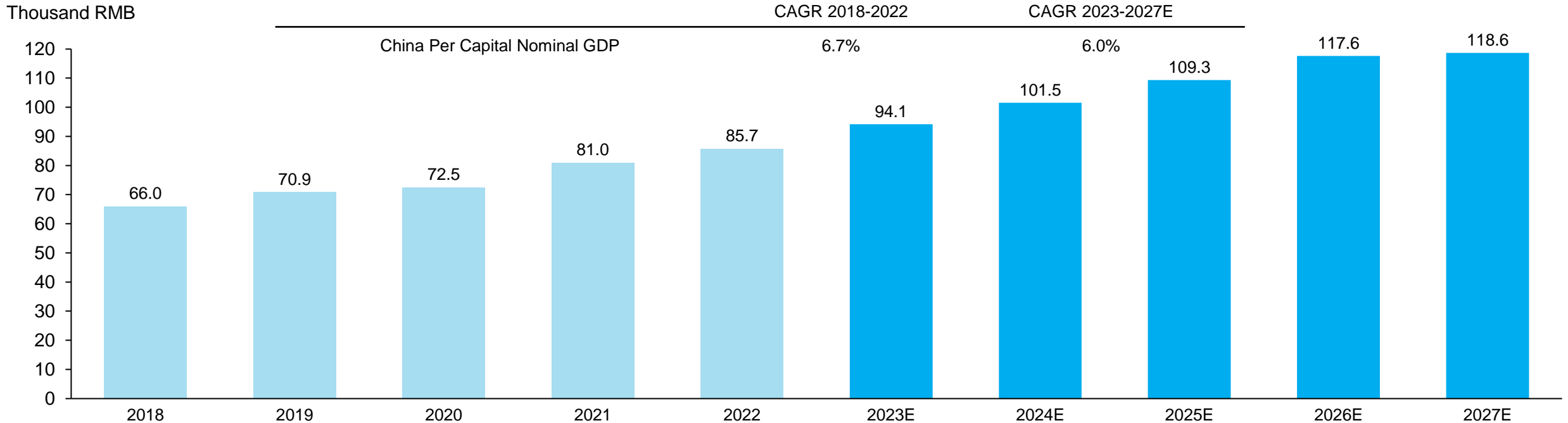


- The outbreak of COVID-19 in January 2020 has temporarily impacted China’s macro economic shortly in Jan 2020. In 2020, Henan nominal GDP was RMB5.4 trillion, which only increased 0.9% compared to 2019. In the post COVID-19 era, China will further enhance its innovation capabilities, create a large domestic market, promote higher levels of reform and opening up, and achieve high-quality economic growth. In 2022, Hena nominal GDP is RMB 6.1 trillion, representing a CAGR of 5.3% from 2018. Based on the continuous transformation and upgrading of economic structure and people’s consumption, the nominal GDP of Henan is expected to maintain a steady growth and reach RMB8.2 trillion in 2027, illustrating a CAGR of approximately 6.0% from 2023 to 2027.
- Jiyuan as an prefecture-level administrative unit directly under the Henan provincial government, the nominal GDP of Henan grew steadily from RMB64.2 billion in 2018 to RMB80.6 billion in 2022 at a CAGR of 5.9%. Jiyuan nominal GDP expected increased from RMB88 billion to RMB115.4 billion over the period of 2023 and 2027 at a CAGR of 7.0%.

Overview of Macro Economic Environment

Per Capital Nominal GDP

Per Capital Nominal GDP (China), 2018-2027E

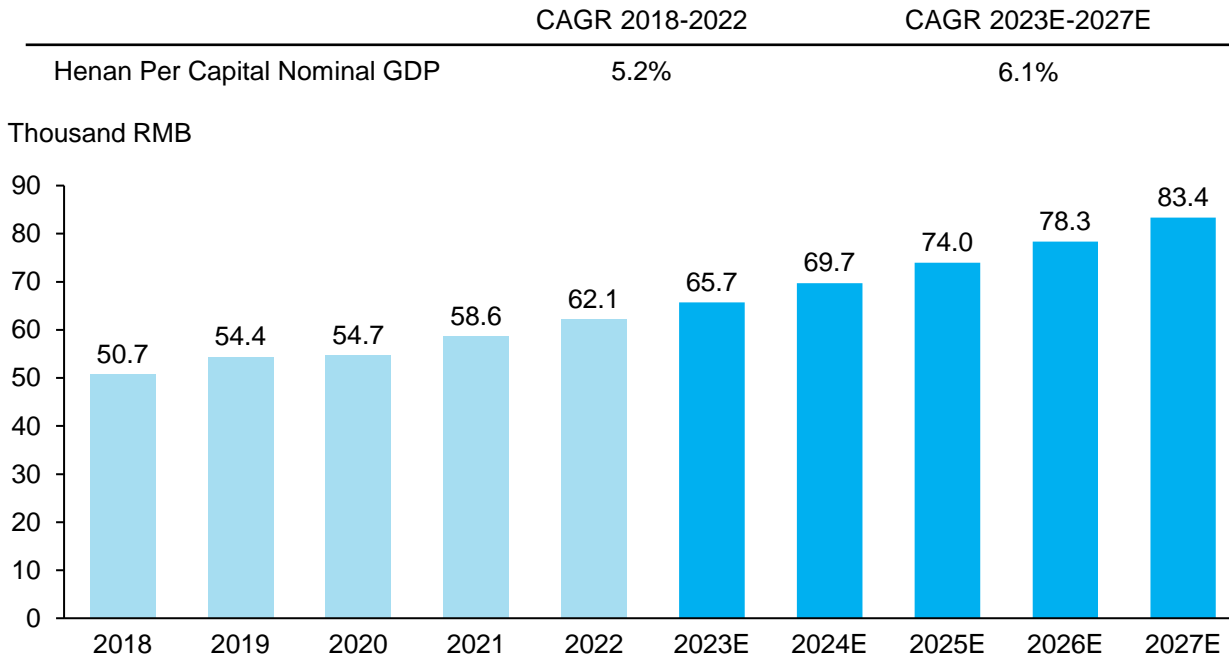


- In line with China's overall economic growth, China's per capita nominal GDP has maintained a rapid growth in the past few years, from RMB66.0 thousand in 2018 to approximately RMB87.3 thousand in 2022, representing a CAGR of approximately 6.7%.
- The growth rate of China's per capita nominal GDP in 2020 slowed down by approximately 2.2% due to COVID-19. Looking forward, driven by factors such as technological innovation and consumption upgrading, China's per capita GDP will maintain steady growth from 2023 to 2027, which is expected to reach RMB118.6 thousand by 2027, representing a CAGR of about 6.0%.

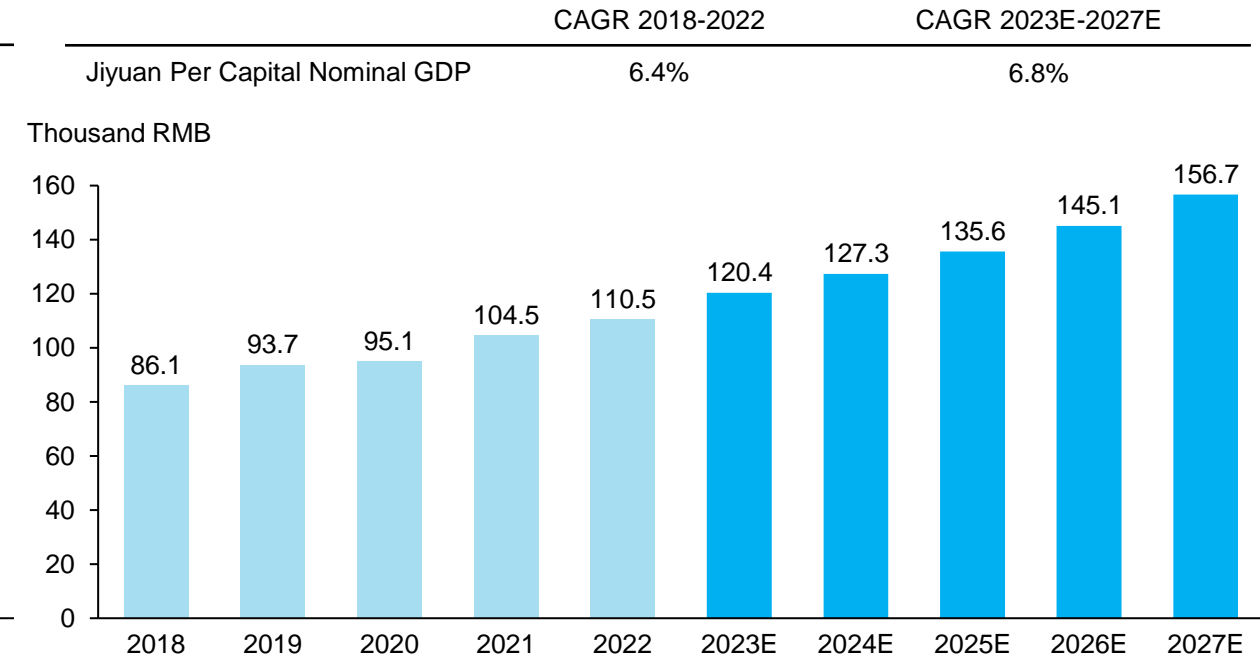
Overview of Macro Economic Environment

Per Capital Nominal GDP

Per Capital Nominal GDP (Henan Province), 2018-2027E



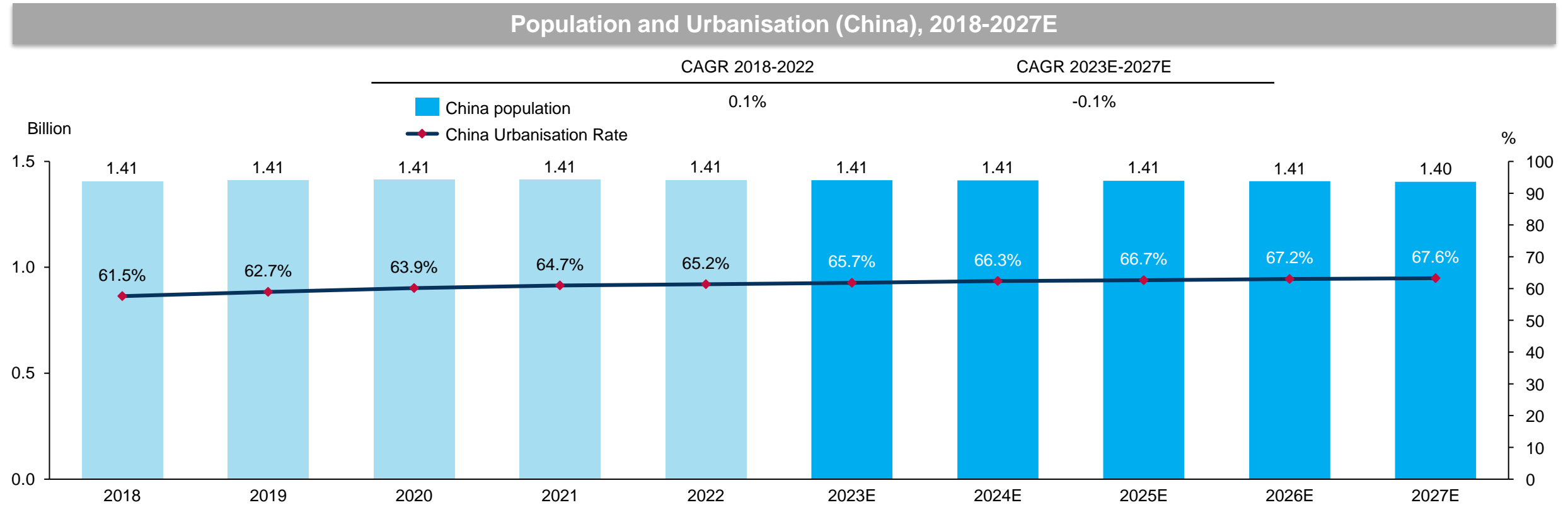
Per Capital Nominal GDP (Jiyuan), 2018-2027E



- Henan per capital nominal GDP grew steadily from RMB50.7 thousand in 2018 to RMB62.1 thousand in 2022, representing a CAGR of 5.2% over the period. The growth rate of Henan's per capital nominal GDP in 2020 slowed down to 0.6%. With the gradual implementation of vaccination, the epidemic was effectively controlled and the economy recovered well in 2021. The per capital nominal GDP of Henan expected to grow from RMB65.7 thousand in 2023 to RMB83.4 thousand in 2027 with a CAGR of 6.1%.
- Jiyuan as a county-level city under the direct jurisdiction of Henan Province, it plays a vital role during the overall development and planning. The per capital nominal GDP of Jiyuan is expected to reach RMB156.7 thousand in 2027, representing a CAGR of 6.8% from 2023 to 2027.

Overview of Macro Economic Environment

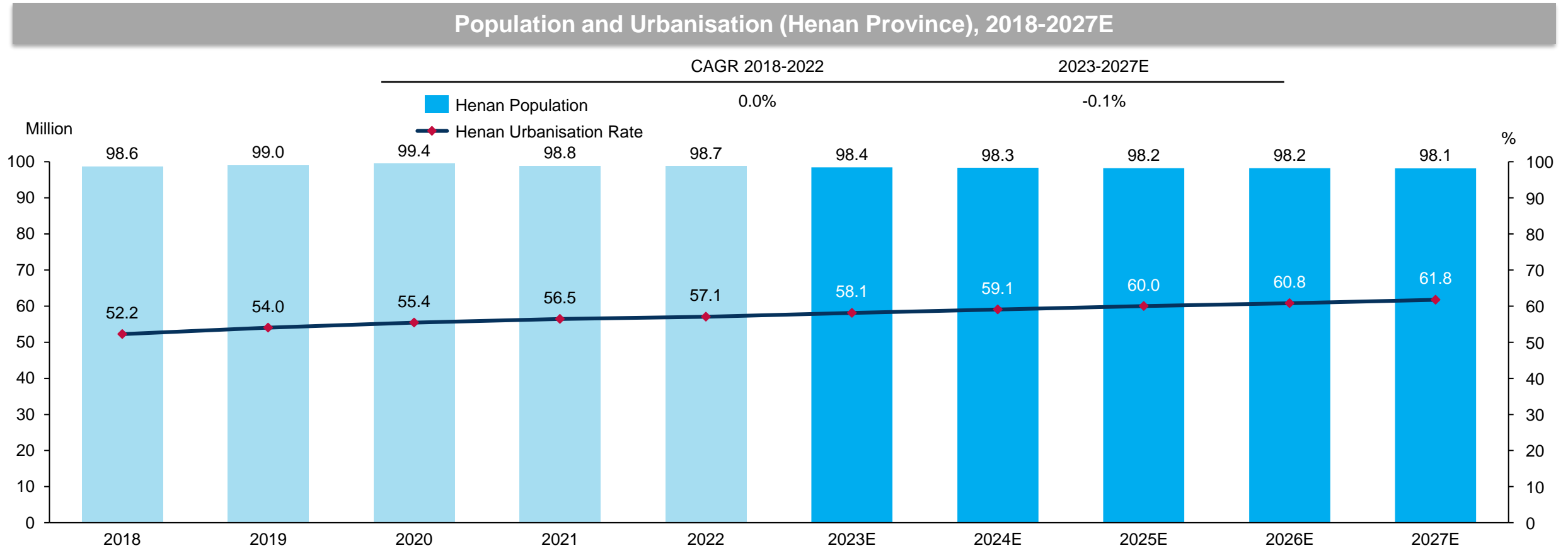
Population and Urbanisation



- The population growth rate has been stable over the past few years. According to the National Bureau of Statistics of China, China's total population reached 1.4 billion in 2022, representing a CAGR of -0.1% between 2023 and 2027. With the in-depth development of new industrialization, informatization and agricultural modernisation and the implementation of the policy of urbanisation of the agricultural transfer population (农业转移人口市民化政策), China's new urbanisation (新型城镇化) process is progressing steadily, and the urbanization construction has made historic achievements. The urbanisation rate in China increased from 61.5% in 2018 and reached 65.2% in 2022. With the continuous growth of urbanisation, the urban population of China is expected to grow further. Under the "National Plan for Promoting Healthy Urbanisation" (全国促进城镇化健康发展规划) raised in 2013, new urbanisation is expected to promote the urban-rural coordination and reasonable distribution. Accordingly, the urbanisation rate is likely to increase gradually from 2023 to 2027, reaching 67.6% by 2027.

Overview of Macro Economic Environment

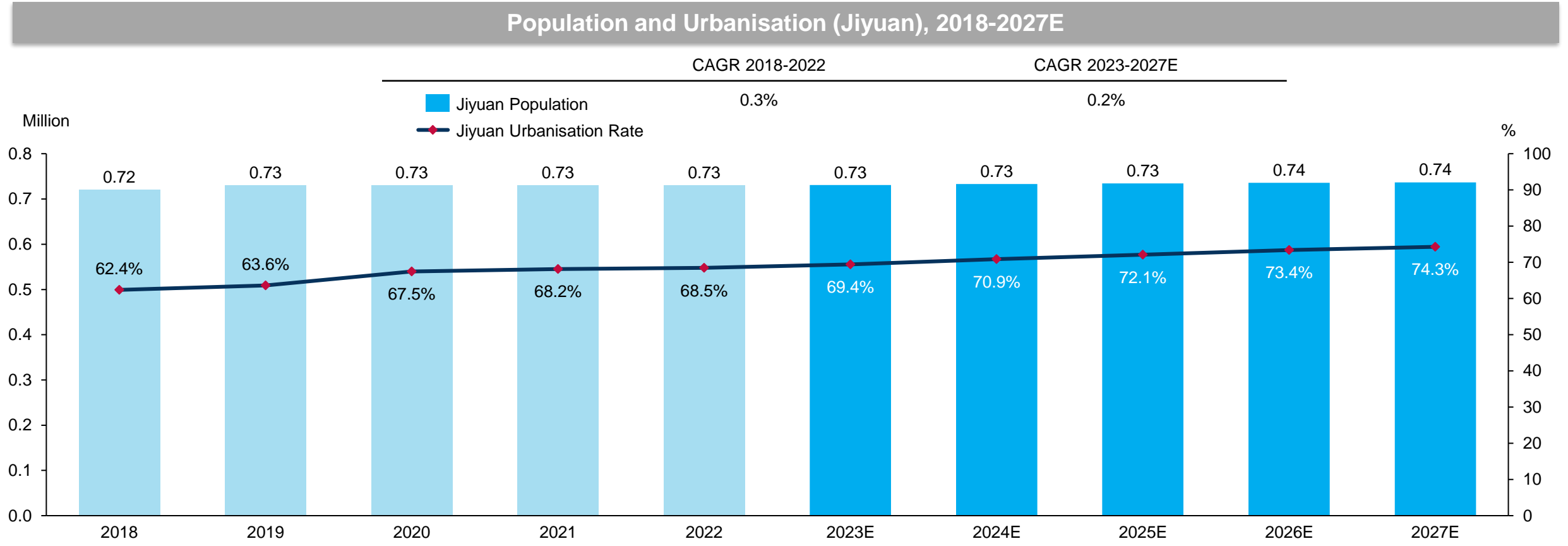
Population and Urbanisation



- In 2022, the population of Henan reached 98.7 million. Due to the development of the economy and 2022. With the in-depth development of new industrialization, informatization and agricultural modernization and the implementation of rural-to-urban migration policy, Henan urbanization keep increasing from 52.2% in 2018 to 57.1% in 2022. The continuous increase in urbanization rate has a positive impact on population numbers. However, in China's persistently low birth rate situation, Henan population expected to increase to 98.1 million at a CAGR of -0.1% between 2023 and 2027.

Overview of Macro Economic Environment

Population and Urbanisation

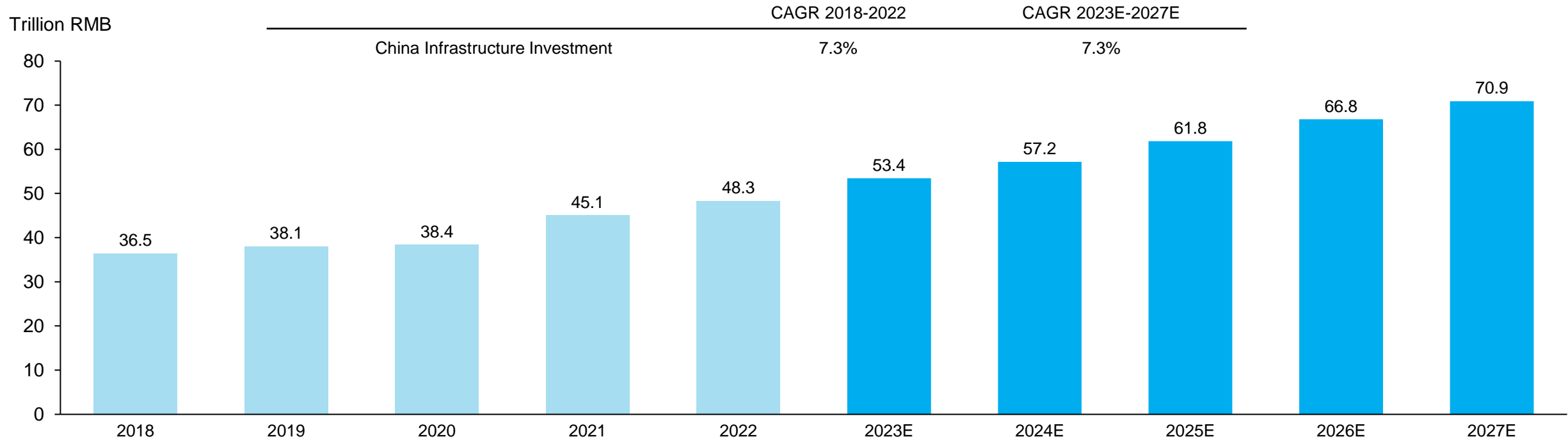


- In 2022, the population of Jiyuan reached 0.73 million, representing a CAGR at 0.3% between 2018 and 2022. Jiyuan urbanization increased from 62.4% in 2018 to 68.5% in 2022
- During the forecast period, the population of Jiyuan will maintain a stable growth at a CAGR of approximately 0.2% and reach 0.74 million by 2027. The urbanisation rate is expected to increase from 69.4% in 2023 to 74.3% in 2027.

Overview of Macro Economic Environment

Infrastructure Investment

Infrastructure Investment (China), 2018-2027E

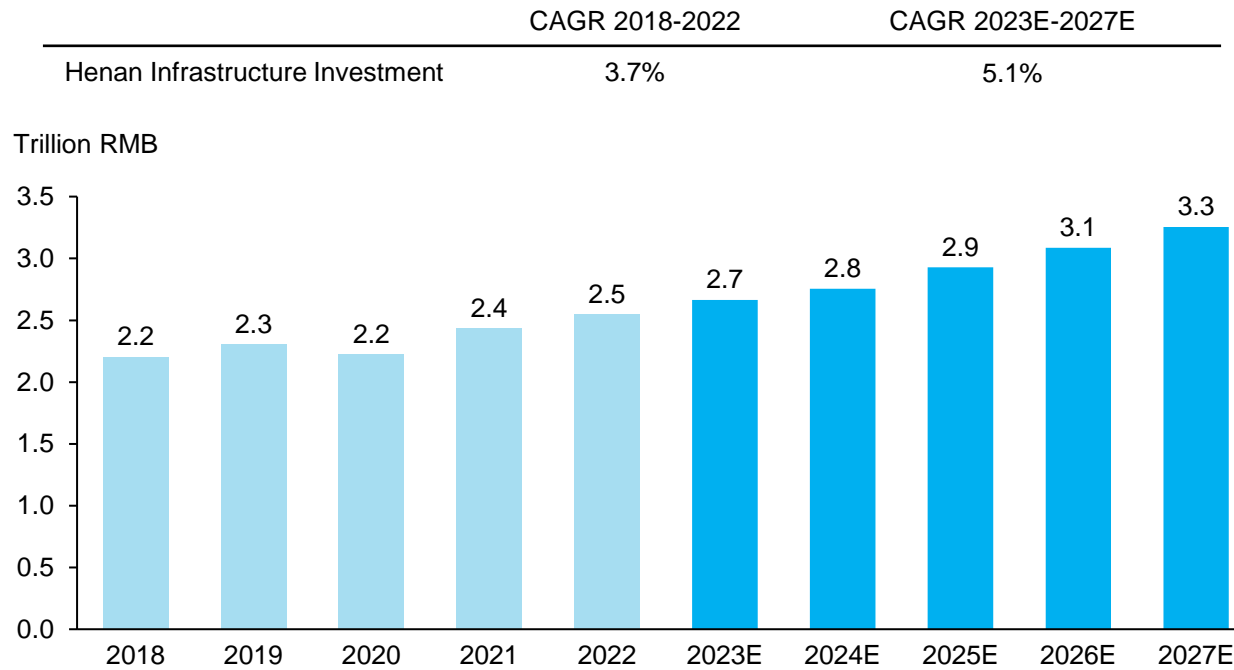


- Infrastructure investment as one of the core driving forces for China's GDP, has shown a steady growth tendency. China infrastructure investment grew from RMB36.5 trillion in 2018 to RMB48.3 trillion in 2022, representing a CAGR of 7.3%. In the post COVID-19 era, China will further enhance its innovation capabilities, create a large domestic market, promote higher levels of reform and opening up, and achieve high-quality economic growth. China infrastructure investment is expected to reach RMB70.9 trillion in 2027, representing a CAGR of 7.3% from 2023.

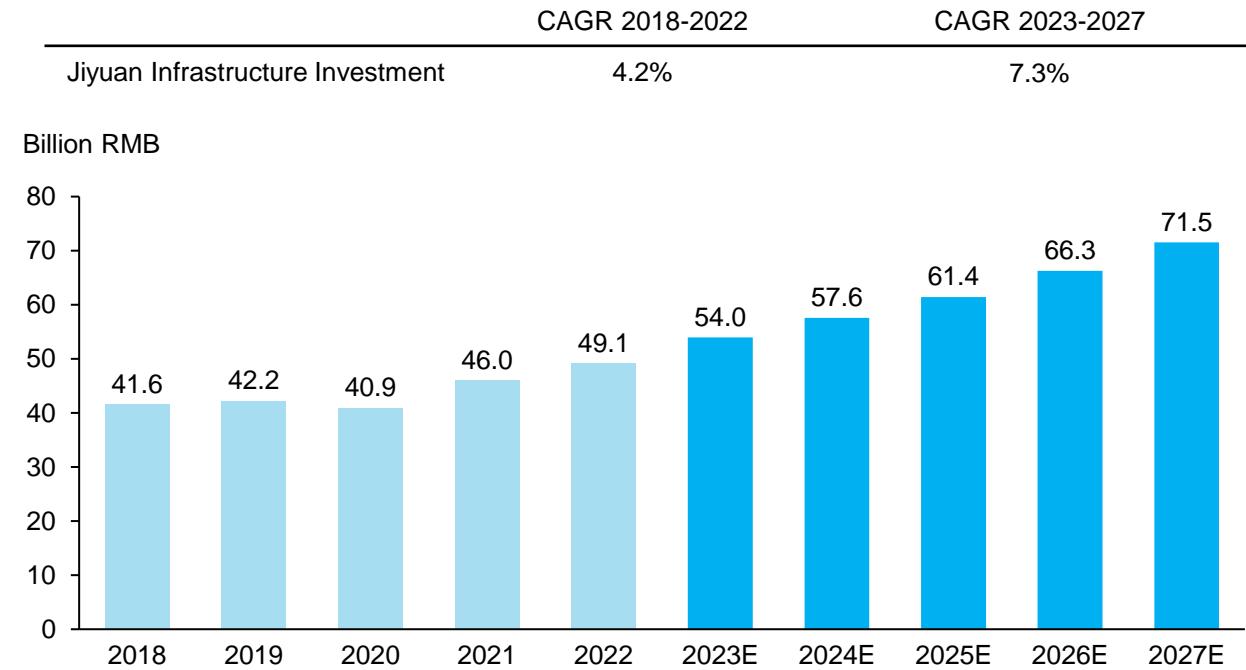
Overview of Macro Economic Environment

Infrastructure Investment

Infrastructure Investment (Henan Province), 2018-2027E



Infrastructure Investment (Jiyuan), 2018-2027E



- With the continuously development of economic growth, Henan infrastructure investment grew from RMB2.2 trillion in 2018 to RMB 2.5 trillion in 2022 with a CAGR of 3.7%; Jiyuan infrastructure investment grew from RMB41.6 billion in 2018 to RMB49.1 billion with a CAGR of 4.2%.
- Henan infrastructure investment is expected to reach RMB3.3 trillion in 2027, representing a CAGR 5.1% from 2023; Jiyuan infrastructure investment is expected to reach RMB71.5 billion in 2027, representing a CAGR 7.3% from 2023.

Agenda

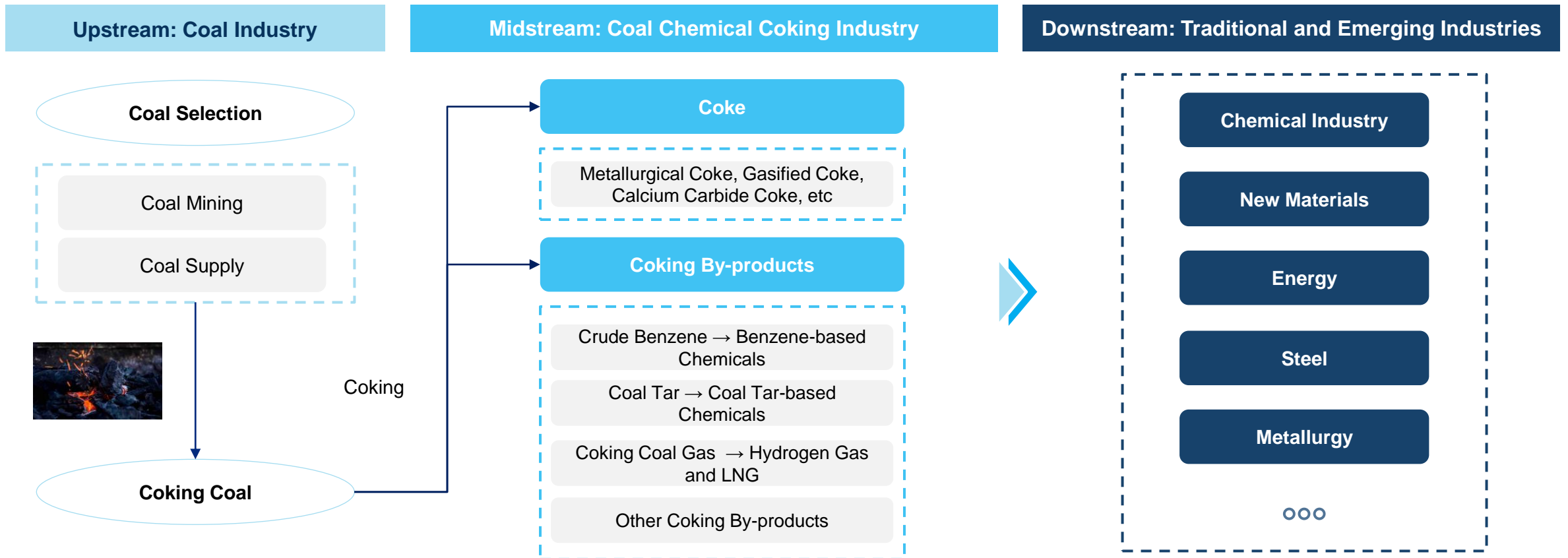
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Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Overview of the Coal Chemical Coking Industry

- Coal chemical industry involves process that uses coal as raw material and undergoes chemical processing to convert coal into gas, liquid, solid fuel and chemicals. It mainly includes three major directions: coking, coal gasification, and coal liquefaction. The coking industry is a major component of the coal chemical industry, and coking coal is the basic raw material for the coal chemical coking industry, constituting the main production cost. In coal chemical coking process, the main products include coke and coking by-products. Coking by-products mainly include crude benzene, coal tar and crude coking coal gas, all of which can be used as raw materials for the production of refined chemicals. In recent years, with the continuous elimination of outdated production capacity, the improvement of production technology, and the extension of their own industrial chains by many coking enterprises, the coal chemical coking industry has gradually become more prominent and has the potential for sustained growth.



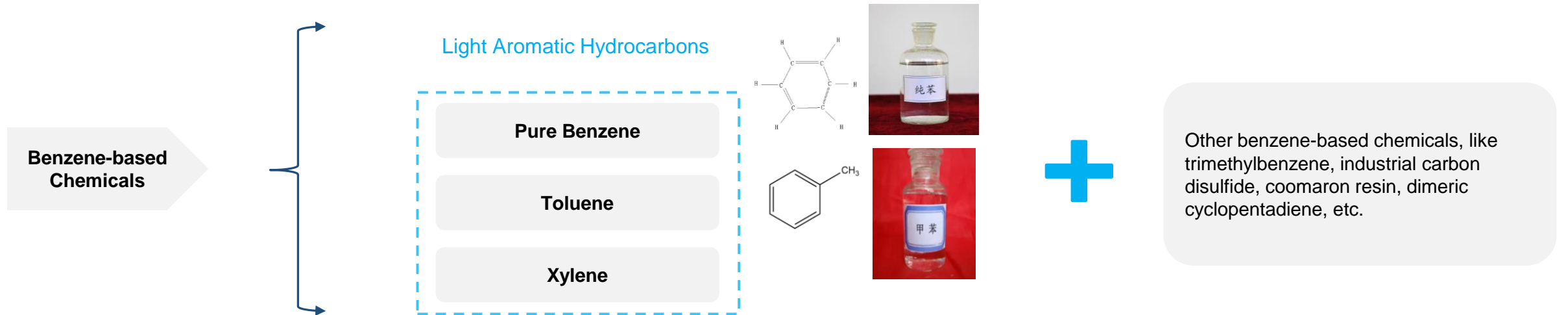
Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Definition and Classification of Benzene-based Chemicals

Definition and Overview of Benzene-based Chemicals

- Benzene-based chemicals refer to chemicals with benzene ring as the functional group, which are mainly extracted from coal and petroleum processing. The method of extracting benzene from coal is to pass the crude benzene and coal gas generated during coking process through the washing and absorbing equipment, using washing oil with high boiling point as washing and absorbing agent to recover the benzene in the coal gas. Industrial grade benzene can be obtained by refining crude benzene, and the main products produced are mainly pure benzene (accounting for about 70%), toluene and xylene.
- Currently, hydrogenation process, the adding of hydrogen in the presence of catalyst, for the purification of crude benzene is environmentally friendly. Compared with other purification process like the earliest pickling method, oxidation method and low-temperature gaseous extraction method, hydrogenation process of crude benzene has less pollution, lower energy consumption, higher product quality and yield, and basically has no quality difference with petroleum benzene (pure benzene obtained from petroleum refinery).

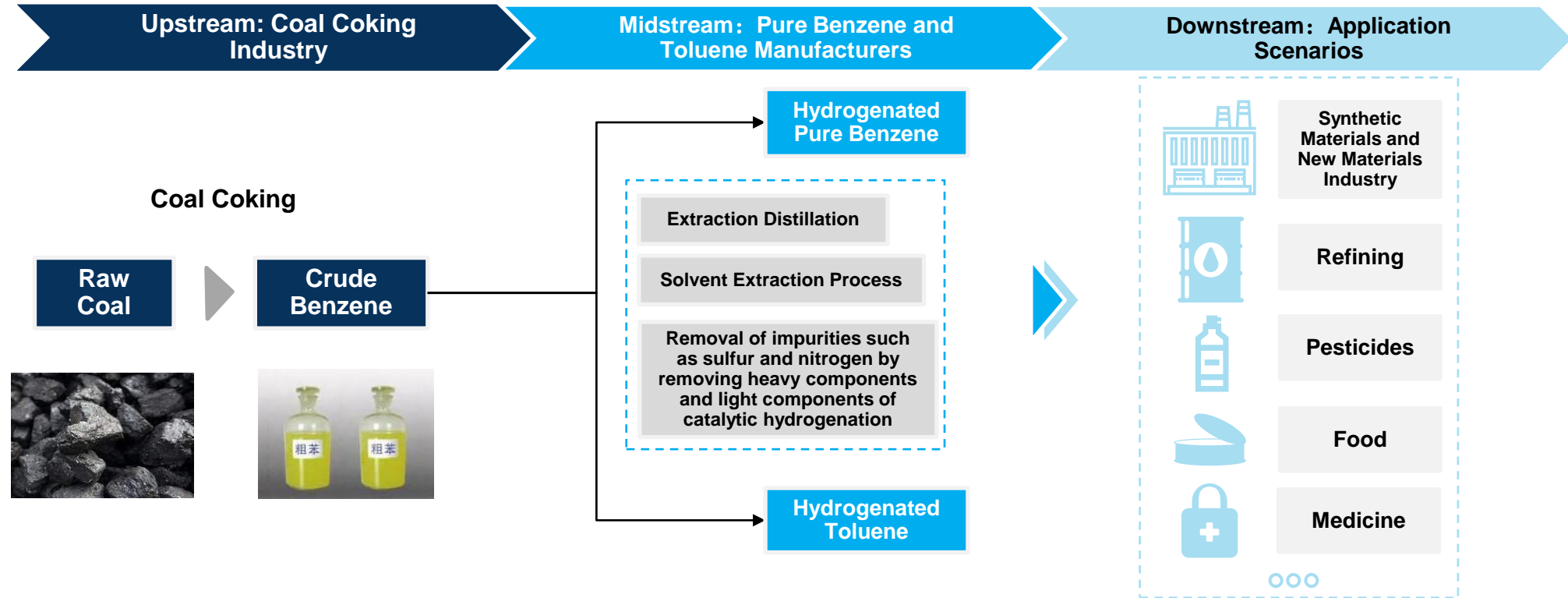
Classification of Benzene-based Chemicals



Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Analysis of the Benzene-based Chemical Industry Chain

Value Chain of the Benzene-based Chemicals Industry (China) (Hydrogenated Pure Benzene and Hydrogenated Toluene)



- Take hydrogenated pure benzene and hydrogenated toluene as an example, the upstream source of raw materials for both hydrogenated pure benzene and hydrogenated toluene comes from crude benzene further processed from raw coal. After a series of processes by midstream manufacturers of pure benzene and toluene (mainly including the removal of impurities such as sulfur and nitrogen by removing heavy components and light components of catalytic hydrogenation, extraction distillation or solvent extraction process), crude benzene gradually becomes hydrogenated pure benzene and hydrogenated toluene. During the midstream manufacturing process, the processing methods are mainly divided into two categories: high-temperature method (600-630°C) and low-temperature method (320-380°C). Among them, the low-temperature method is the main method for the production of hydrogenated pure benzene in China. A series of indicators such as economy and environmental protection in the production of midstream market participants determine the development and production capacity construction of pure benzene and toluene manufacturers. The downstream chemical raw materials products are widely used in the synthetic materials and new materials industry, refining, pesticides, food, medicine, and other traditional and emerging industries. Therefore, benzene-based chemicals represented by pure benzene and toluene are one of the fundamental raw materials for the production in petrochemical industry.

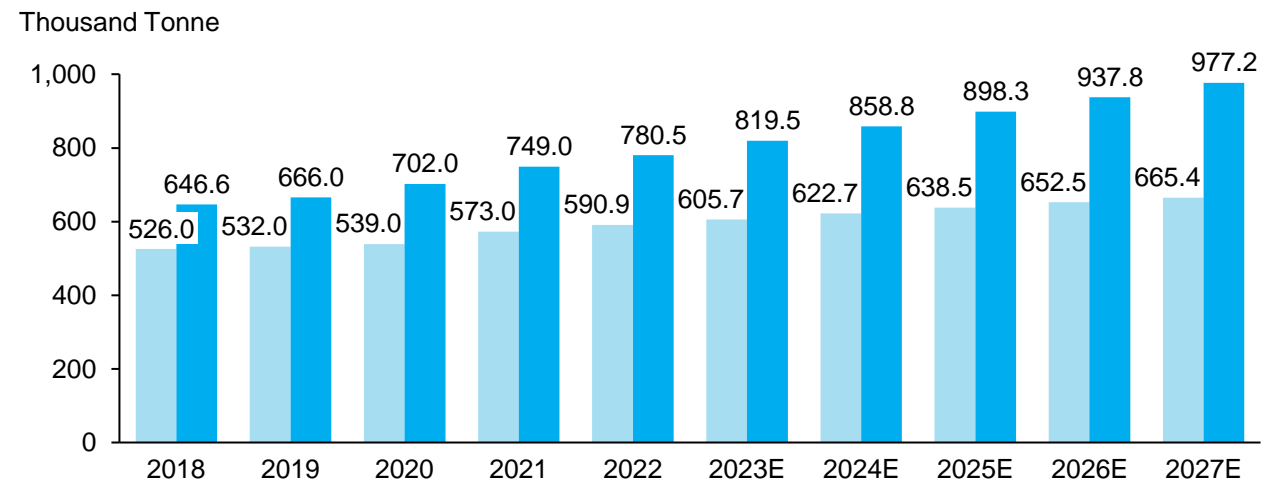
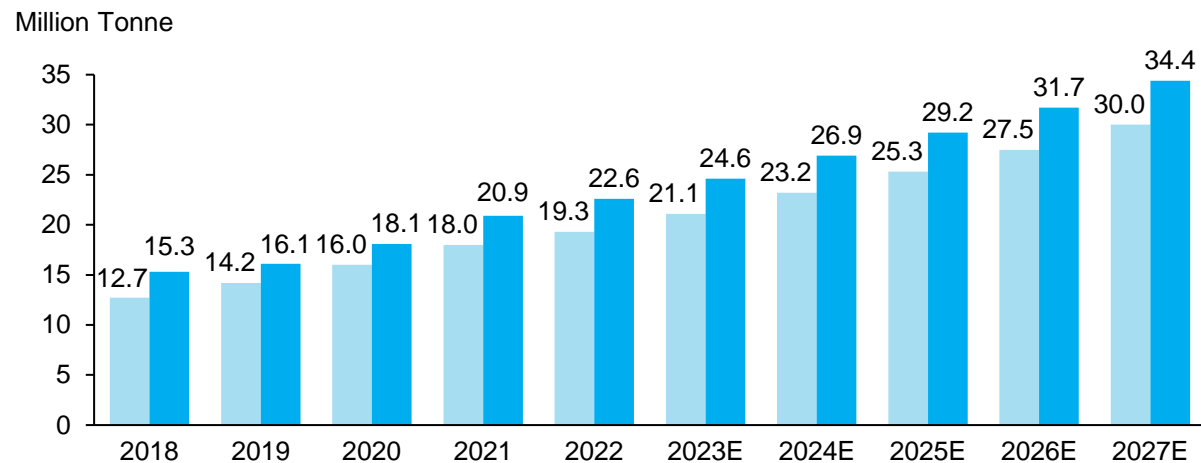
Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Market Size of Pure Benzene in China and Henan Province

Production and Sales Volume of Pure Benzene (China and Henan Province), 2018-2027E

	CAGR 2018-2022	CAGR 2023E-2027E
Pure Benzene Production Volume in China	10.9%	9.1%
Pure Benzene Sales Volume in China	10.3%	8.7%

	CAGR 2018-2022	CAGR 2023E-2027E
Pure Benzene Production Volume in Henan Province	3.0%	2.4%
Pure Benzene Sales Volume in Henan Province	4.8%	4.5%

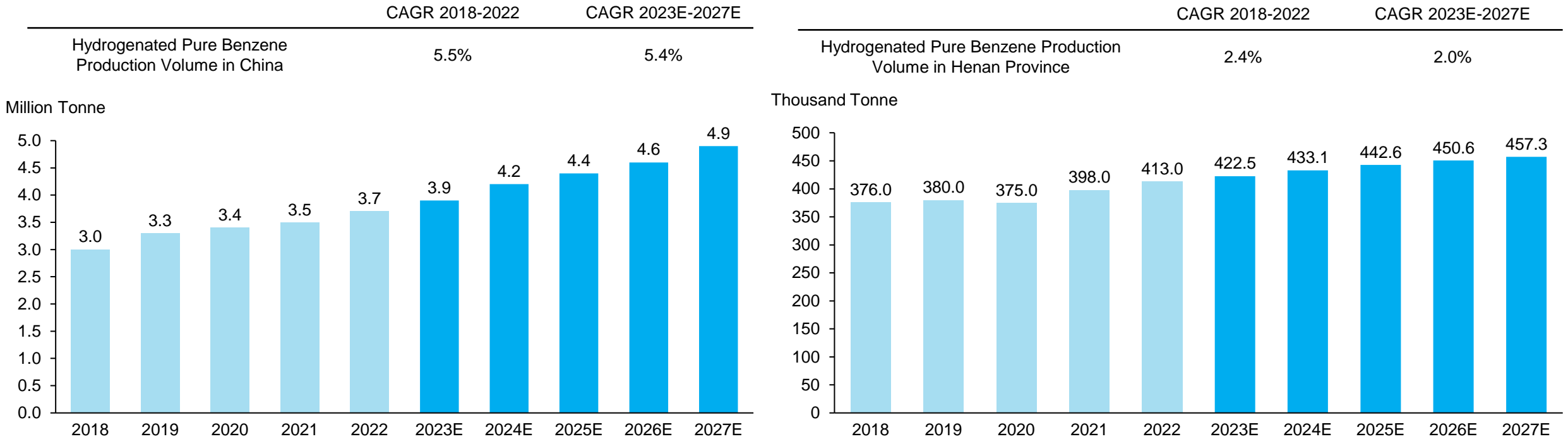


- With the continuous and steady development of China's macroeconomy, manufacturing industry, and industrial sector, the production and sales volume of pure benzene in China have maintained a steady growth. The production volume of pure benzene in China increased from 12.7 million tonnes in 2018 to 19.3 million tonnes in 2022, with a CAGR of 10.9%. China's pure benzene is dependent on imports, and the annual sales volume continues to be higher than the annual production. The sales volume of pure benzene in China increased from 15.3 million tonnes in 2018 to 22.6 million tonnes in 2022, with a CAGR of 10.3%. In recent years, the production and sales volume of pure benzene in China has maintained a steady growth trend. In the future, the production volume of pure benzene in China is expected to increase from 21.1 million tonnes in 2023 to 30.0 million tonnes in 2027, with a CAGR of 9.1%. The sales volume of pure benzene in China is expected to increase from 24.6 million tonnes in 2023 to 34.4 million tonnes in 2027, with a CAGR of 8.7%.
- Similar to the trend of the production and sales volume of pure benzene, the production volume of pure benzene in Henan province increased from 526.0 thousand tonnes in 2018 to 590.9 thousand tonnes in 2022, with a CAGR of 3.0%. The sales volume of pure benzene in Henan province continued to be higher than the annual production, requiring supply from other provinces to meet the demand within the province. The sales volume of pure benzene in Henan province increased from 646.6 thousand tonnes in 2018 to 780.5 thousand tonnes in 2022, with a CAGR of 4.8%. With the continuous development of relevant downstream industries in Henan province in the future, the production volume of pure benzene in Henan province is expected to increase from 605.7 thousand tonnes in 2023 to 665.4 thousand tonnes in 2027, with a CAGR of 2.4%. Meanwhile, the sales volume of pure benzene in Henan province is expected to increase from 819.5 thousand tonnes in 2023 to 977.2 thousand tonnes in 2027, with a CAGR of 4.5%.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Market Size of Hydrogenated Pure Benzene in China and Henan Province

Production and Sales Volume of Hydrogenated Pure Benzene (China and Henan Province), 2018-2027E



• There are many coal chemical coking enterprises in China, while only the coal chemical coking enterprises with leading technology have the output of hydrogenated pure benzene. China's hydrogenated pure benzene production increased from 3.0 million tonnes in 2018 to 3.7 million tonnes in 2022, with a CAGR of 5.5% during the period. In the future, with the development of hydrogenated pure benzene technology and the expansion of application fields, the production of hydrogenated pure benzene in China is expected to increase from 3.9 million tonnes in 2023 to 4.9 million tonnes in 2027, with a compound annual growth rate of 5.4% during the period. As Henan Province is a concentration of coal chemical coking enterprises, Henan Province is one of the main hydrogenated pure benzene producers in China, and the production of hydrogenated pure benzene in Henan Province increased from 376.0 thousand tonnes in 2018 to 413.0 thousand tonnes in 2022, with a compound annual growth rate of 2.4% during the period. In 2022, the production of hydrogenated pure benzene in Henan Province accounted for 69.9% of the pure benzene production, which was much higher than the proportion of domestic hydrogenated pure benzene in the production of pure benzene. In the future, the production of hydrogenated pure benzene in Henan Province is expected to increase from 422.5 thousand tonnes in 2023 to 457.3 thousand tonnes in 2027, with a compound annual growth rate of 2.0% during the period.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

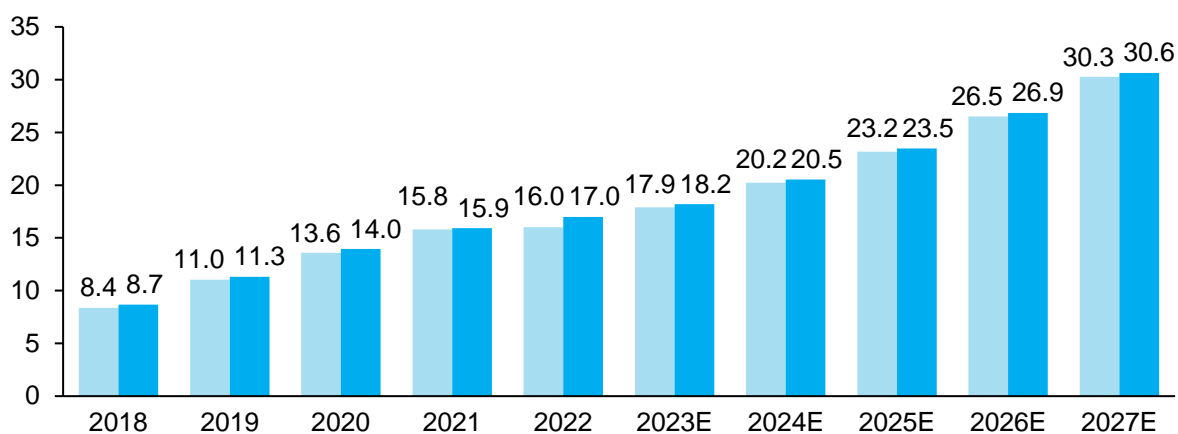
Market Size of Toluene in China and Henan Province

Production and Sales Volume of Toluene (China and Henan Province), 2018-2027E

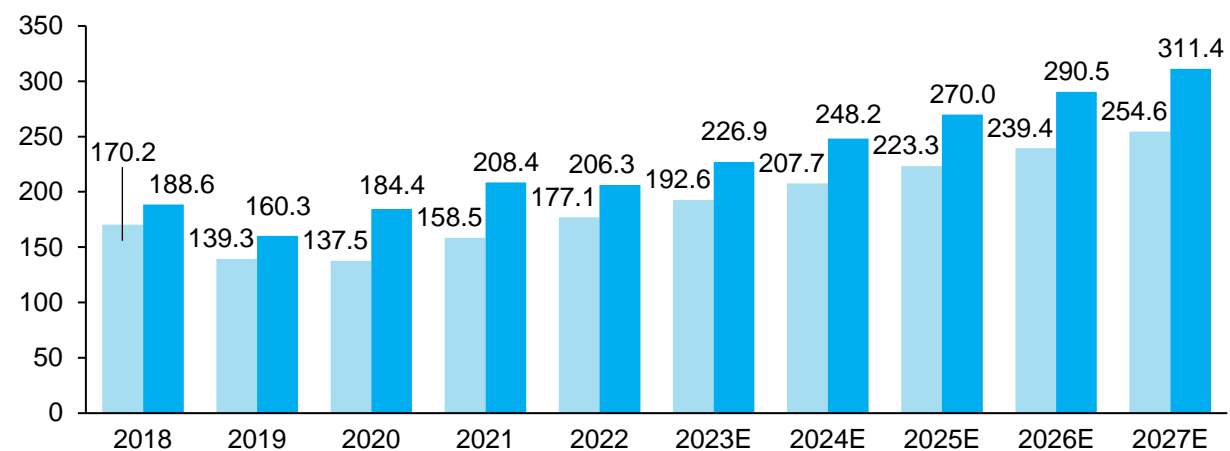
	CAGR 2018-2022	CAGR 2023E-2027E
Toluene Production Volume in China	17.6%	14.1%
Toluene Sales Volume in China	18.3%	13.9%

	CAGR 2018-2022	CAGR 2023E-2027E
Toluene Production Volume in Henan Province	1.0%	7.2%
Toluene Sales Volume in Henan Province	2.3%	8.2%

Million Tonne



Thousand Tonne

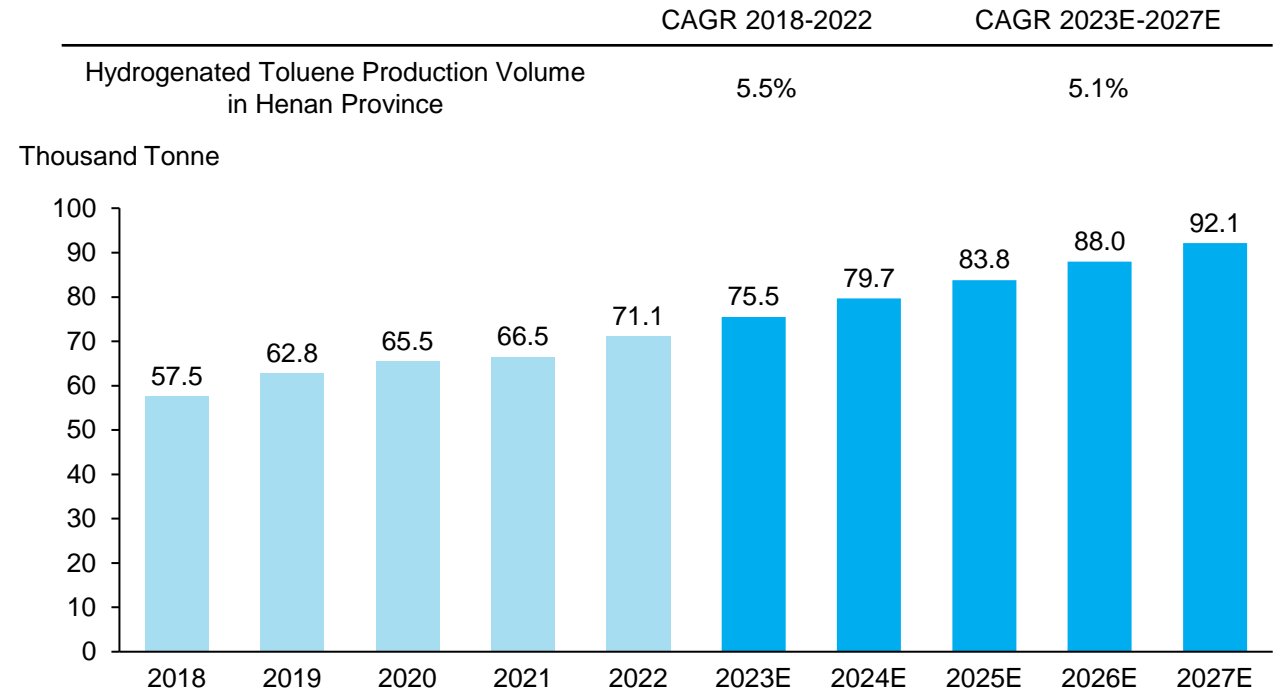
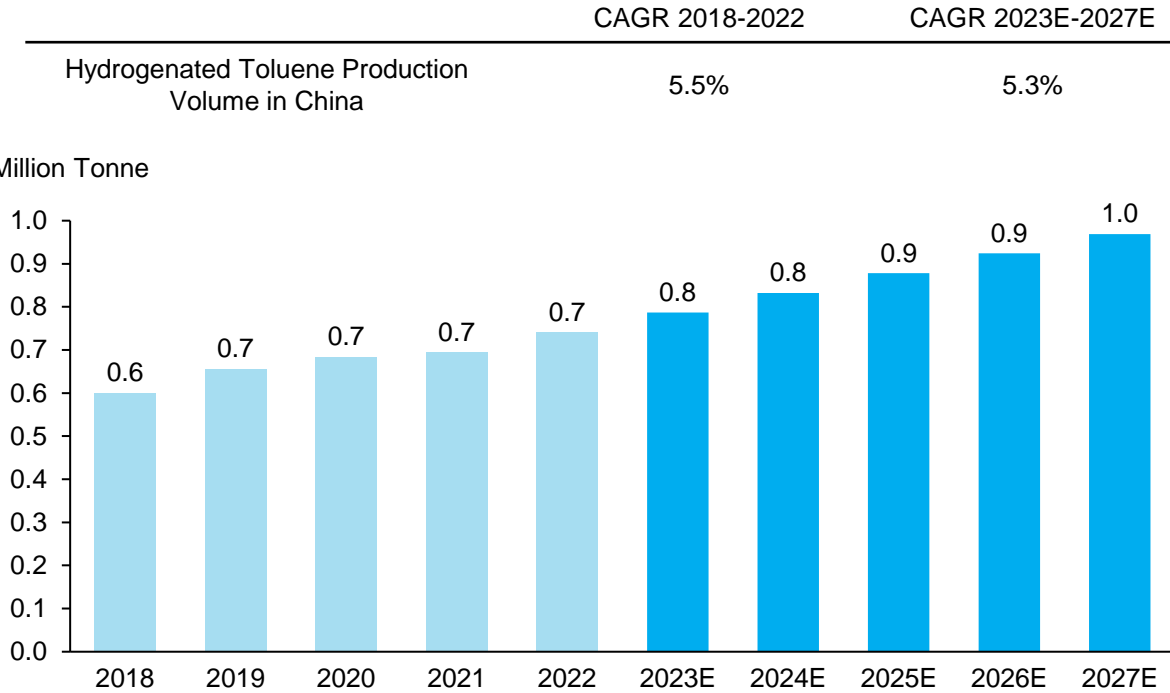


- Hydrogenated toluene maintains a fast development pace, helping to drive the continuous growth of the production and sales volume of toluene in China to meet downstream demand. The production volume of toluene in China increased from 8.4 million tonnes in 2018 to 16.0 million tonnes in 2022, with a CAGR of 17.6%. The sales volume of toluene in China increased from 8.7 million tonnes in 2018 to 17.0 million tonnes in 2022, with a CAGR of 18.3%. In the future, with the expansion of downstream markets and products in the toluene industry and the continuous development of the macroeconomy, the production volume of toluene in China is expected to increase from 17.9 million tonnes in 2023 to 30.3 million tonnes in 2027, with a CAGR of 14.1%. The sales volume of toluene in China is expected to increase from 18.2 million tonnes in 2023 to 30.6 million tonnes in 2027, with a CAGR of 13.9%.
- Similar to the pure benzene industry, the production volume of toluene in Henan province has remained stable with a slight increase over the past five years, growing from 170.2 thousand tonnes in 2018 to 177.1 thousand tonnes in 2022, with a CAGR of 1.0%. The sales of toluene in Henan province continued to be higher than the annual production. The sales volume of toluene in Henan province increased from 188.6 thousand tonnes in 2018 to 206.3 thousand tonnes in 2022, with a CAGR of 2.3%. In the future, driven by downstream demand, the production volume of toluene in Henan province is expected to increase from 192.6 thousand tonnes in 2023 to 254.6 thousand tonnes in 2027, with a CAGR of 7.2%. Meanwhile, the sales volume of toluene in Henan province is expected to increase from 226.9 thousand tonnes in 2023 to 311.4 thousand tonnes in 2027, with a CAGR of 8.2%.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Market Size of Hydrogenated Toluene in China and Henan Province

Production and Sales Volume of Hydrogenated Toluene (China and Henan Province), 2018-2027E



- Similar to the production trend of hydrogenated pure benzene, the hydrogenated toluene industry has developed steadily with the technological progress of coal chemical coking enterprises. China's hydrogenated toluene production increased from 0.6 million tonnes in 2018 to 0.7 million tonnes in 2022, with a CAGR of 5.5% during the period. In the future, with the technological development and continuous penetration of hydrogenated toluene, China's hydrogenated toluene production is expected to increase from 0.8 million tonnes in 2023 to 1.0 million tonnes in 2027, with a compound annual growth rate of 5.3% during the period.
- As one of the main hydrogenated toluene production bases in China, the production of hydrogenated toluene in Henan Province increased from 57.5 thousand tonnes in 2018 to 71.1 thousand tonnes in 2022, with a compound annual growth rate of 5.5% during the period. In 2022, the production of hydrogenated toluene in Henan Province accounted for 40.1% of toluene production, which was higher than the proportion of hydrogenated toluene in China. In the future, the production of hydrogenated toluene in Henan Province is expected to increase from 75.5 thousand tonnes in 2023 to 92.1 thousand tonnes in 2027, with a compound annual growth rate of 5.1% during the period.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Market Drivers and Developing Trends for Benzene-Based Chemicals

Policy support for the sustainable development of the benzene-based chemicals industry

Policies such as the “Implementation Guidelines on Renovation and Upgrading of Energy Saving and Carbon Reduction for Modern Coal Chemical Industry” (《現代煤化工行業節能降碳改造升級實施指南》) and the “Action Plan for Industrial Energy Efficiency Improvement” (《工業能效提升行動計劃》) launched and implemented in 2022 focus on the realisation of green technology and craftsmanship, the allocation of major energy-saving equipment in the production process of modern coal chemical industry and benzene-based chemicals, as well as the safeguarding of the optimisation of the energy system, the utilisation of residual heat and pressure, the renovation of public and auxiliary facilities, the comprehensive utilisation of wastes, and the refined control of the whole process, while promoting the intensive and green development of heavy chemicals. Therefore, the continuous introduction of policies effectively supports the sustainable, green, and high-speed development of the coal chemical coking industry and the benzene-based chemical industry.

China’s abundant coal resources ensure a stable supply of by-products from coal coking

The sources of main upstream raw material for benzene-based chemicals are coal and petroleum. Unlike the dependence on imports of oil, China is the world’s largest coal producer and has the ability to produce the raw coal needed for various downstream industries. Therefore, after achieving high purity product quality in hydrogenated pure benzene and hydrogenated toluene, they can be benchmarked against petroleum pure benzene and petroleum toluene. At the same time, China’s abundant and stable development of coal resources has contributed to the stable development of hydrogenated pure benzene and hydrogenated toluene. Taking some large coke production enterprises as an example, they are gradually shifting their production focus from coke with lower production profits to increasing the production capacity of coking by-products, achieving higher profits and ensuring the sustainable development of the enterprises. Therefore, with a stable supply of coal resources, the supply of by-products from coal coking is also becoming stable, and the market size of benzene-based chemicals will continue to grow.

The demand for benzene-based chemicals in the downstream market will rise continuously

Both pure benzene and toluene are basic organic chemical raw materials in the chemical industry. The downstream market of pure benzene is mainly composed of chemical products such as styrene and caprolactam, among which styrene occupies a larger market share in the downstream. As a monomer for synthetic rubber and plastics, styrene is mainly used to produce butadiene rubber, polystyrene, expandable polystyrene, etc. It is also used to manufacture various engineering plastics. The widespread application of benzene-based chemicals in various industries will ensure stable demand in the downstream market, driving the development and capacity expansion of the overall benzene-based chemical market.

The production technology of benzene-based chemicals is developing towards low carbon and low pollution

The coal chemical coking industry is a capital and technology-intensive industry. At present, the investment scale of a single project is large, as it needs to meet the national and local environmental protection standards and capacity supporting requirements before the construction of plants. With the realisation of hydrogenated pure benzene in the process of processing by-product benzene by coal, the technology of benzene-based chemicals has been significantly improved and the environmental protection effect has been remarkable. In general, due to the characteristics of benzene hydrogenation process such as low pollution, safe operation, low investment and good quality, the production technology of benzene-based chemicals will continue to converge towards hydrogenated pure benzene, achieving low-carbon and low-pollution development with policy support.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Barriers to Enter into the Benzene-based Chemicals Industry

1

Technical Barrier

- Hydrogenation process, the adding of hydrogen in the process of catalyst, for the purification of crude benzene is environmentally friendly. However, most enterprises find it difficult to master the technology, so the leading enterprises have formed certain technology barriers.

2

Capital Barrier

- The coal chemical coking industry, especially manufacturers of benzene-based chemicals, belongs to a capital-intensive industry that requires substantial initial funding to support the construction of benzene-based chemicals plants, purchase production equipment required for benzene-based chemicals, ensure the utilisation rate and proper planning of production equipment, and meet the environmental assessment requirements of the country and local authorities. New entrants find it difficult to achieve, thus forming a capital barrier.

3

Supply Barrier

- The construction of new production capacity for benzene-based chemicals needs to meet purification standards to ensure continuous supply. Currently, all new domestic coke oven projects require capacity replacement, and policies in various regions adopt the approach of “equivalent or reduced capacity replacement”. Therefore, new entrants are restricted by environmental protection and new construction standards, making it difficult to expand production capacity in a short time.

4

Qualification Barrier

- As an enterprise in benzene-based chemicals industry, the prerequisite is to obtain the relevant qualifications and independent management rights for the operation of pure benzene, toluene and other products in China. At the same time, according to the Regulations of the People's Republic of China on the Administration of Production Licenses for Industrial Products, when selling related chemical raw materials, it is necessary to apply for a hazardous chemical business license, and the specific situation needs to be changed according to the type and specifications of benzene products. In addition, the Coking Industry Specification Conditions standardizes the standards of environmental management and emphasizes the importance of environmental protection qualifications, thus forming a qualification barrier for the industry.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Threats and Challenges to Enter into the Benzene-based Chemicals Industry

- **Challenges and Risks from Potential Entrants**

With the deepening of China's global trade development, the huge market will attract many foreign large chemical companies to enter the Chinese market by building factories or investing in China, while foreign benzene-based chemicals and their downstream products will also enter China with the reduction of tariffs, and some large domestic petrochemical enterprises also have new or expanded production plans, so the threat from potential entrants is also increasing. These potential entrants will bring new capacity and resources to the benzene-based chemicals industry, while competing for market share with existing benzene-based chemical companies, which ultimately leads to a decrease in the profitability of existing companies in the industry.

- **Complex Macro-economic Development Situation**

Due to the wide application of the downstream industry, the benzene-based-based chemicals market is related to the macroeconomy and the overall development of the chemical industry. However, the macroeconomic situation is affected by multiple factors at home and abroad, and the economic development situation and the trend of change are closely related to international relations and different national policies, and there is a certain degree of uncertainty. For example, international trade frictions may bring about an imbalance between the demand and supply of benzene-based chemicals, making the downstream chemical industry and manufacturing industry lack certainty, resulting in greater challenges for benzene-based chemical manufacturing enterprises.

- **The "Dual Carbon" Goal Affects the Development of the Benzene-based Chemicals Industry**

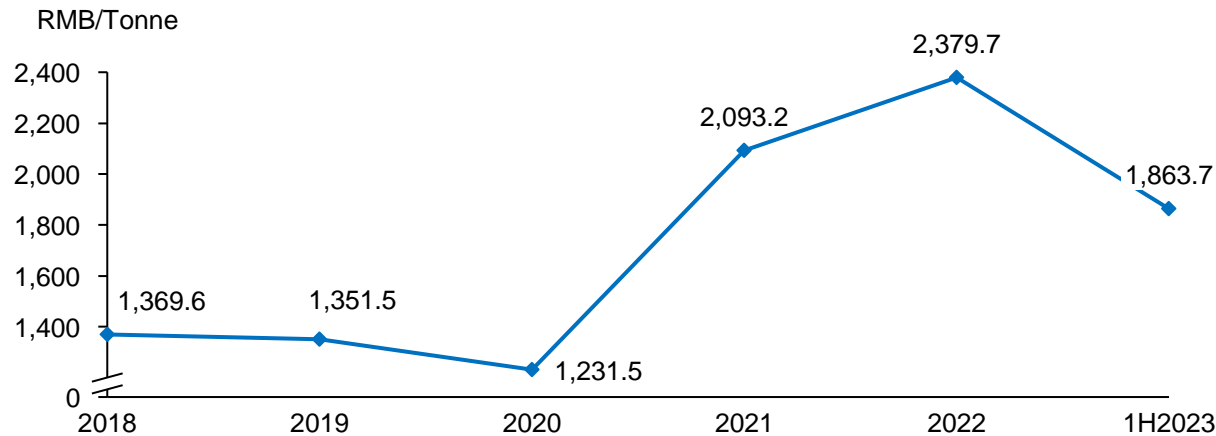
As the world's largest energy producer and consumer, the Chinese government has put forward the "dual carbon" goal of carbon peak and carbon neutrality, which has a non-negligible impact on the development of coal chemical coking industry and benzene-based chemicals, and the national environmental impact assessment standards are also improving year by year and becoming more stringent. Therefore, in the "dual carbon" goal, enterprises may be affected by economic changes and national policies on "dual carbon", and are subject to restrictions on the start of production equipment and the expansion of new production capacity such as dual control of energy consumption and carbon emission restrictions, which will affect corporate profits and market expansion.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

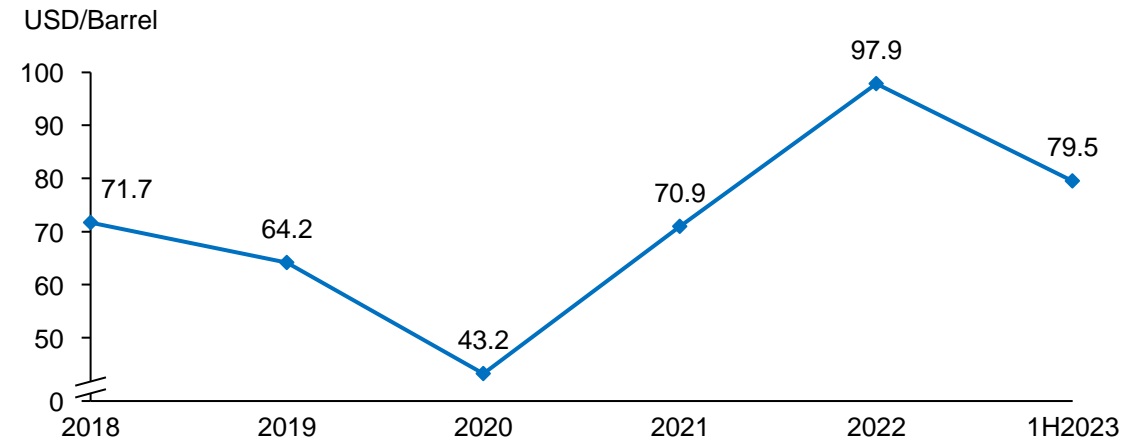
Price Analysis of Raw Materials and Products for Benzene-based Chemicals

Pure benzene, a main product of benzene-based chemicals, can be extracted from both coal and petroleum processing, whereas for crude benzene, a principal raw material for benzene-based chemicals, can only be extracted from coal processing. Currently, pure benzene extracted from petroleum processing contributed to a larger market share than that extracted from coal processing in China. As such, the price of pure benzene is affected by, to a larger extent, the price of petroleum, which in turn is affected by the price of crude oil. The price trend of crude benzene also depends on the price trend of pure benzene (which is ultimately affected by the price of crude oil) due to the relatively larger market share of pure benzene. As such, the price of crude benzene will be ultimately affected by the price of crude oil, similar to pure benzene. Meanwhile, the prices of crude benzene and benzene-based chemicals are influenced by the prices of coking coal to some extent.

Prices of Coking Coal in China, 2018-1H2023



Prices of Brent Crude Oil , 2018-1H2023



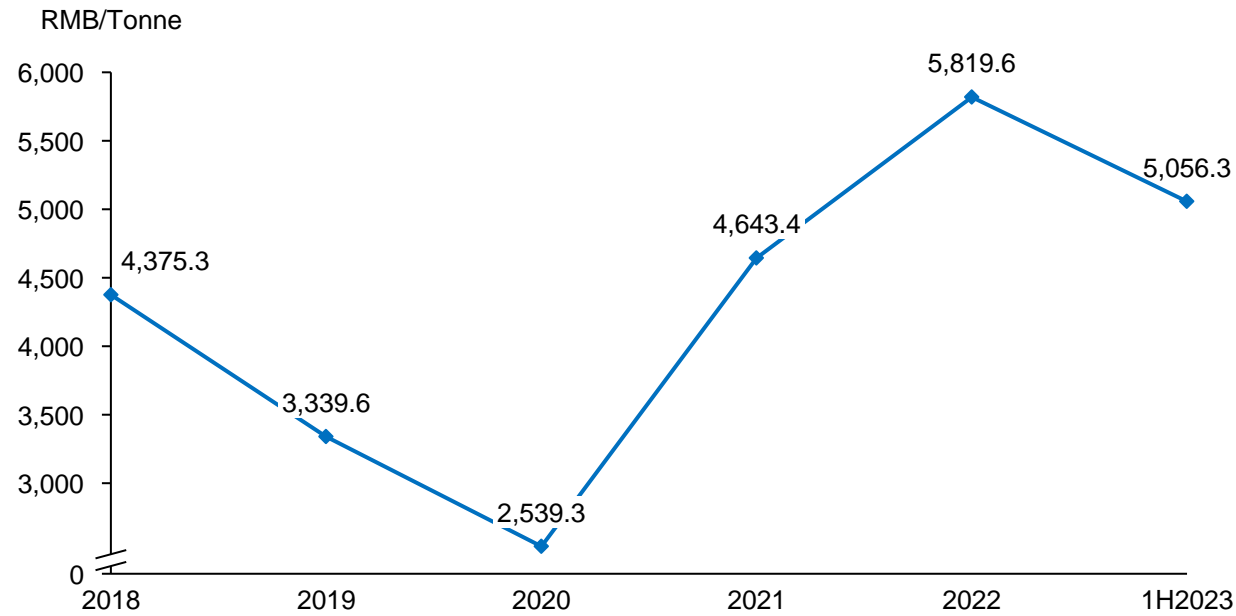
- From 2018 to 2019, the price of coking coal in China remained relatively stable, with a slight decrease in 2020 due to the impact of the COVID-19 pandemic. Since 2021, the supply of coking coal market in China has been relatively tight due to factors such as the recovery in demand after the pandemic and restrictions on coking coal production under strict environmental protection policies (e.g., energy consumption dual control). In 2022, impacted by the rising international energy price after the outbreak of Russian-Ukrainian conflict, the price of coking coal in China experienced a further increase, reaching RMB2,379.7 per tonne. With the implementation of measures to ensure the stable price and supply of coal by the government, the supply of coking coal in the market is gradually recovering. In 1H2023, the price of coking coal in China recovered to RMB1,863.7 per tonne.
- The price of Brent crude oil is normally affected by numerous factors including the balance between supply and demand, geopolitics, the intervention of organizations like OPEC and the macro-economic environment. Affected by the COVID-19 pandemic, the price of Brent crude oil fell to USD43.2 per barrel in 2020, and then gradually recovered to USD70.9 per barrel in 2021. In 2022, due to the outbreak of the Russian-Ukrainian conflict, the price of Brent crude oil rose to USD97.9 per barrel. In 1H2023, the price of Brent crude oil pulled back to USD79.5 per barrel.

Note: The price above is excluding VAT.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Price Analysis of Raw Materials and Products for Benzene-based Chemicals

Prices of Crude Benzene in China, 2018 -1H2023



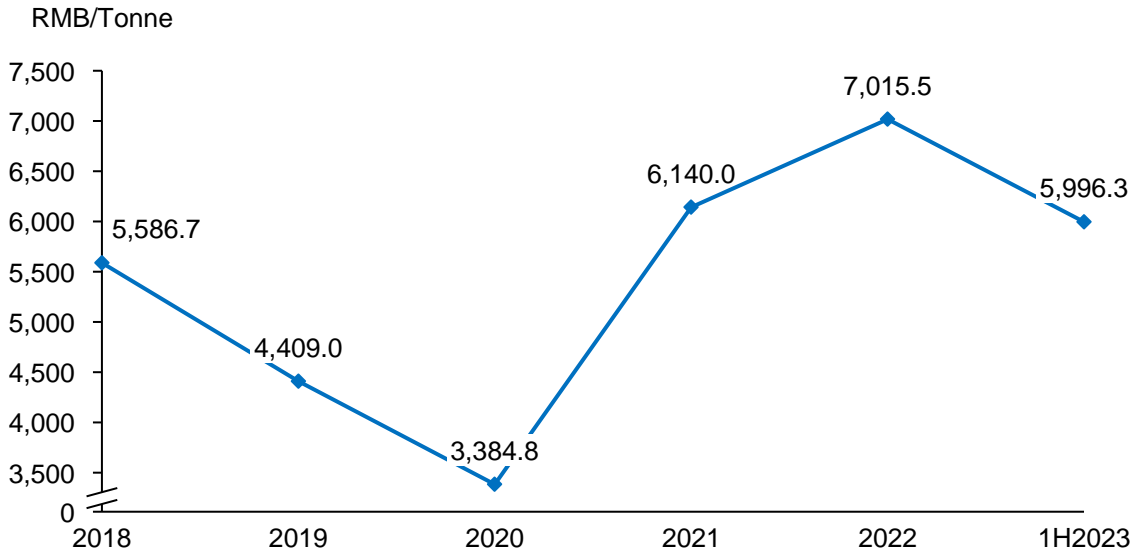
- The price of crude benzene, an upstream raw material for benzene-based chemicals, decreased from RMB4,375.3/tonne in 2018 to approximately RMB2,539.3/tonne in 2020, and then rebounded to RMB5,819.6/tonne in 2022. In 1H2023, it slightly dropped to a normal price range of RMB5,056.3/tonne.

Note: The price above is excluding VAT.

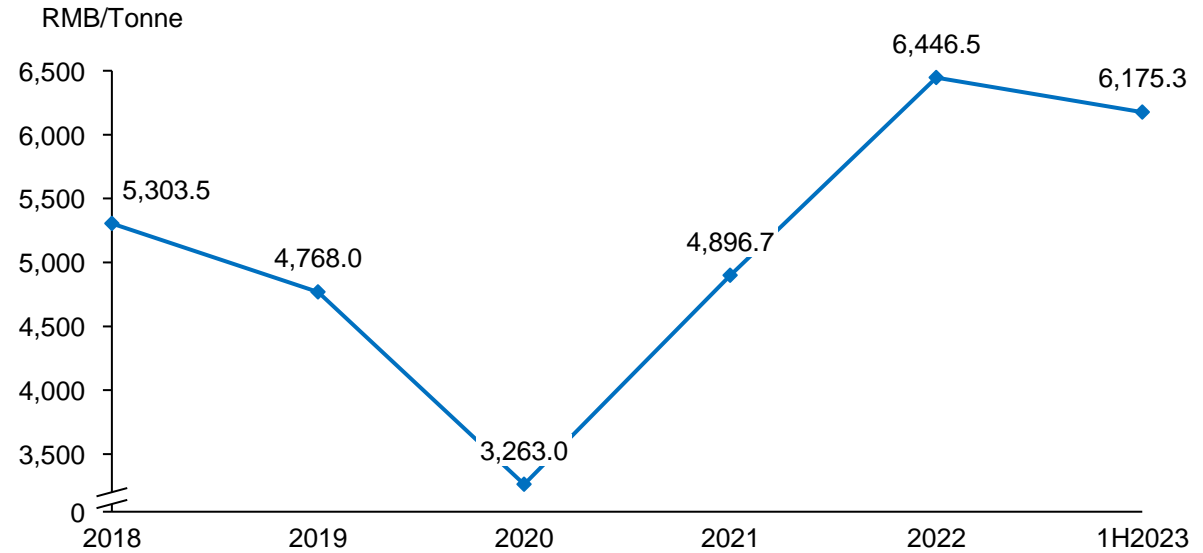
Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Analysis of Prices of Raw Materials and Products for Benzene-based Chemicals

Prices of Pure Benzene in China, 2018 -1H2023



Prices of Toluene in China, 2018 -1H2023



- The price of pure benzene in China was affected by the fluctuation of upstream raw materials, dropping from RMB5,586.7/tonne in 2018 to RMB3,384.8/tonne in 2020. After that, with the recovery of the economy and the rise in raw material prices, the price of pure benzene in China rose to RMB7,015.5/tonne in 2022 and recovered to RMB5,996.3/tonne in 1H2023. The price trend of toluene in China is similar to that of pure benzene, which decreased from RMB5,303.5/tonne in 2018 to RMB3,263.0/tonne in 2020. With the increase in the price of raw material, it gradually rose to RMB6,446.5/tonne in 2022 and recovered to RMB6,175.3/tonne in 1H2023.

Note: The price of crude benzene, pure benzene and toluene is excluding VAT.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

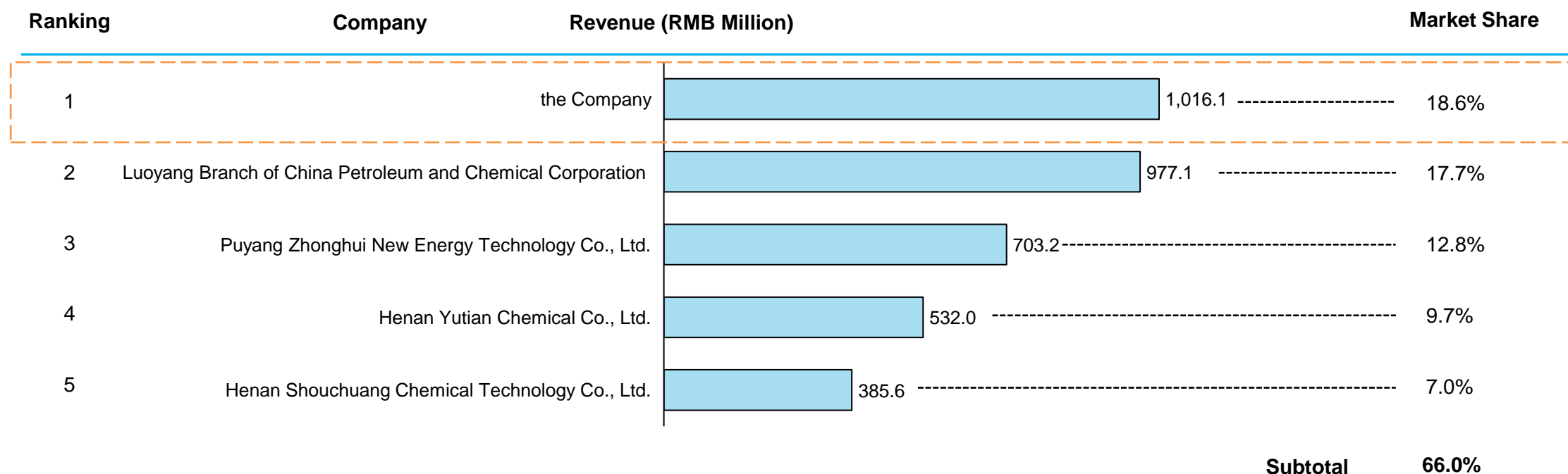
Analysis of Benzene-based chemicals Industry Policies and Regulations

Policy Names	Issuance Time	Issuance Department	Major Contents
Guiding opinions on further promoting the green development of industry in the Yellow River Basin 《关于深入推进黄河流域工业绿色发展的指导意见》	2022.12	National Development and Reform Commission, Ministry of Industry and Information Technology, etc.	<ul style="list-style-type: none"> The opinions promote the clustering, greening and park-based development of chemical, coking, casting, alumina and other industries in the Fenwei Plain, focus on enterprises in the Yellow River Basin coking, modern coal chemical industry and other industries, carry out industrial energy conservation supervision, and strengthen the supervision and inspection of the implementation of energy conservation laws and regulations and mandatory energy conservation standards. In addition, through process carbon reduction, process carbon reduction, and raw material substitution, the carbon reduction of the production process is realized, the deep processing of the industry is promoted, and the industrial structure adjustment and upgrading are gradually completed. At the same time, we will promote the intensive and green development of heavy chemical industry and strictly control the new production capacity of modern coal chemical industry.
Industrial Energy Efficiency Improvement Action Plan 《工业能效提升行动计划》	2022.6	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> The plans use by-product gas from iron and steel and coking enterprises to produce high value-added chemical products, and promote refining and coal chemical enterprises to build an industrial chain that is end-to-end and interconnected with supply and demand and production equipment. Comprehensively give full play to the role of binding indicators such as energy intensity, quality, safety and environmental protection, and accelerate the elimination of backward production capacity.
Guiding opinions on promoting the high-quality development of the petrochemical industry in the 14th Five-Year Plan 《关于“十四五”推动石化化工行业高质量发展的指导意见》	2022.4	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> Opinions promote industrial restructuring. The first is to strengthen classification policies, scientifically regulate the industrial scale of traditional chemical industries such as coal chemical industry, orderly promote the "oil reduction and increase" of refining and chemical projects, and promote the high-end, diversified and low-carbon development of the coal chemical industry. The second is to dynamically update the catalogue of technologies and products encouraged by the petrochemical industry to promote and apply, accelerate the transformation and upgrading of advanced applicable technologies, optimize the structure of olefins and aromatic fuel raw materials, accelerate the extension of coal-to-chemicals and coal-to-oil and gas to high value-added products, and improve the technical level and competitiveness.
Implementation Guide for Energy Conservation and Carbon Reduction Upgrading in Modern Coal Chemical Industry 《现代煤化工行业节能降碳改造升级实施指南》	2022.2	National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Ecology and Environment, National Energy Administration	<ul style="list-style-type: none"> The guides accelerate the popularization and promotion of mature processes, and promotes transformation and upgrading in an orderly manner. Realize the configuration of green technology and major energy-saving equipment, ensure the optimization of energy system, waste heat and pressure utilization, transformation of public auxiliary facilities, comprehensive utilization of waste and refined control of the whole process. Highlight the energy cascade utilization of modern coal chemical industry, and strengthen the comprehensive utilization of ash and slag resources. At the same time, the modern coal chemical industry should strictly meet the restrictive policies, eliminate backward and inefficient production capacity, and accelerate the elimination and withdrawal of coal chemical production capacity that cannot be upgraded through energy-saving transformation and meet the benchmark value.
Outline of the 14th Five-Year Plan for the development of the coking industry 《焦化行业“十四五”发展规划纲要》	2021.1	China Coking Industry Association	<ul style="list-style-type: none"> The outlines combine environmental governance to resolve excess capacity and optimize industrial layout and industrial structure; Increase industrial concentration and strengthen intensive development; Establish a new format of integration with related industries, make use of existing equipment and production capacity, give full play to the advantages of dry distillate function and high energy conversion efficiency of coke ovens, open up new fields of application of coke, coke oven gas and coal tar deep processing products, and realize deep industrial integration with modern coal chemical, metallurgy, fertilizer, petrochemical, building materials and other industries. Further strengthen the research and development and promotion and application of key technologies, processes and equipment in the industry; Develop coking process informatization and intelligent technology to improve the level of intelligent manufacturing; Promote the application of automation and information control technology in the production organization and operation management of the coking industry.
Coking industry normative conditions 《焦化行业规范条件》	2020.6	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> It standardizes the standards of process and equipment, product quality and environmental management in the coking industry, including conventional coke ovens, semi-coke carbonization furnaces, heat recovery coke ovens, etc.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Competitive Landscape of Henan Pure Benzene Industry

Top Five Pure Benzene Companies by Revenue (Henan Province), 2022

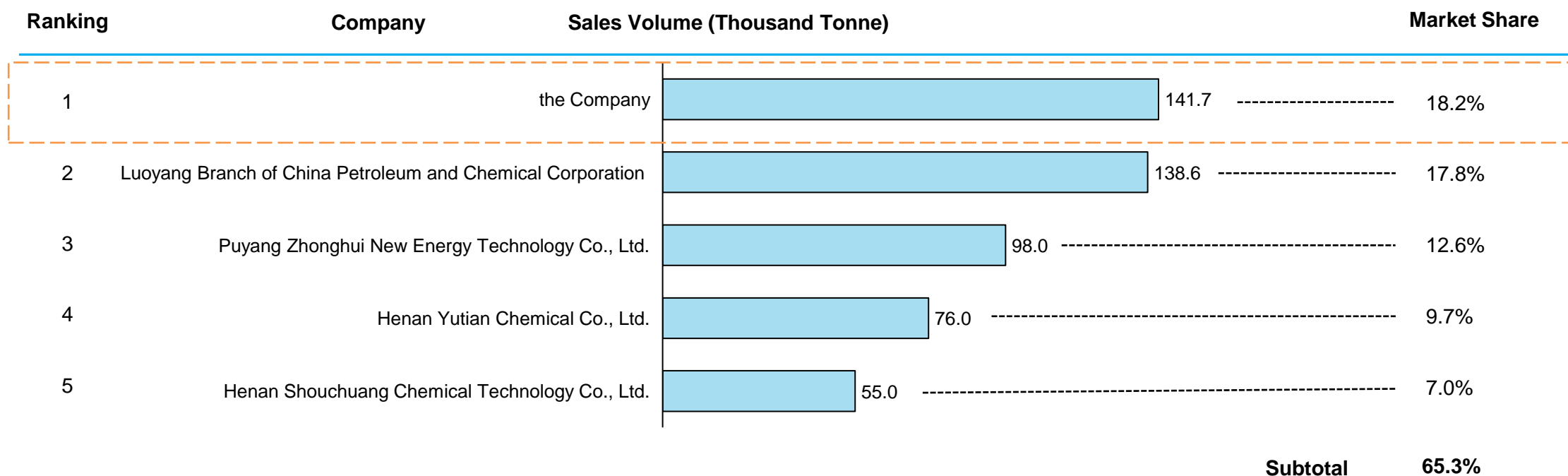


- There are two major types of players in the benzene-based chemicals market, namely, (i) petrochemical companies which derive their benzene-based chemicals from petroleum refinery; and (ii) hydrogenated benzene-based chemical manufacturing companies which derive their benzene-based chemicals from hydrogenation of crude benzene.
- In 2022, the market size of pure benzene in Henan province in terms of revenue was approximately RMB5,475.6 million, of which the top five companies accounted for about 66.0% of the total market size. In 2022, the Company's revenue of pure benzene was RMB1,016.1 million with a market share of 18.6%, ranking first in the industry.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Competitive Landscape of Henan Pure Benzene Industry

Top Five Pure Benzene Companies by Sales Volume (Henan Province), 2022

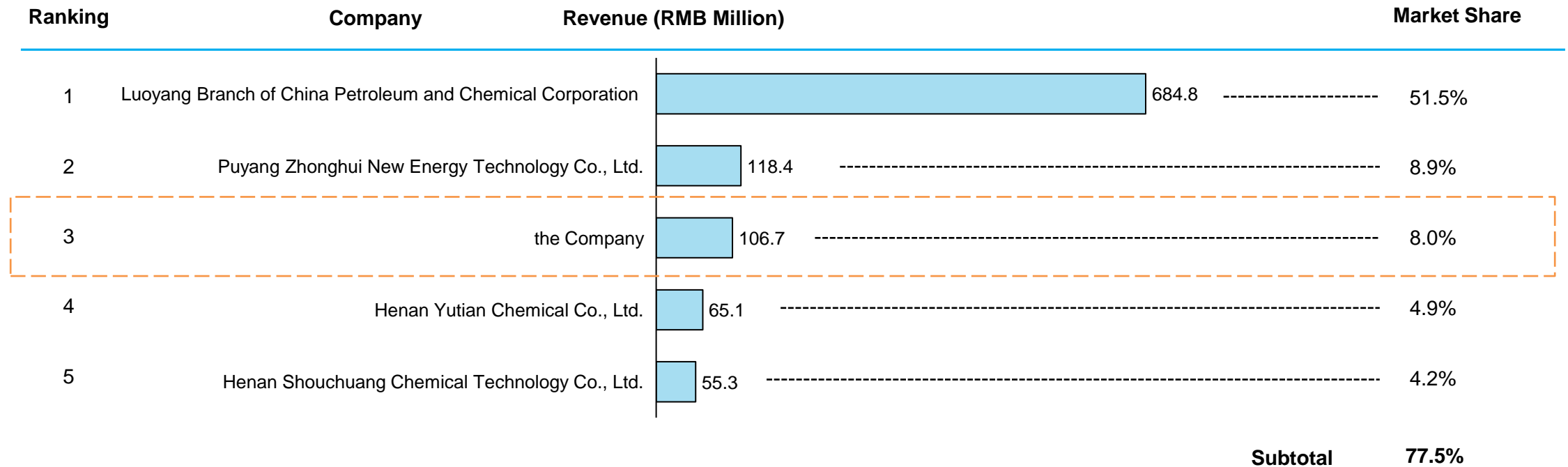


- In 2022, the market size of pure benzene in Henan province in terms of sales volume was approximately 780.5 thousand tonnes, of which the top five companies accounted for about 65.3% of the total market size. In 2022, the Company's sales volume of pure benzene was 141.7 thousand tonnes with a market share of 18.2%, ranking first in the industry.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Competitive Landscape of Henan Toluene Industry

Top Five Toluene Companies by Revenue (Henan Province), 2022

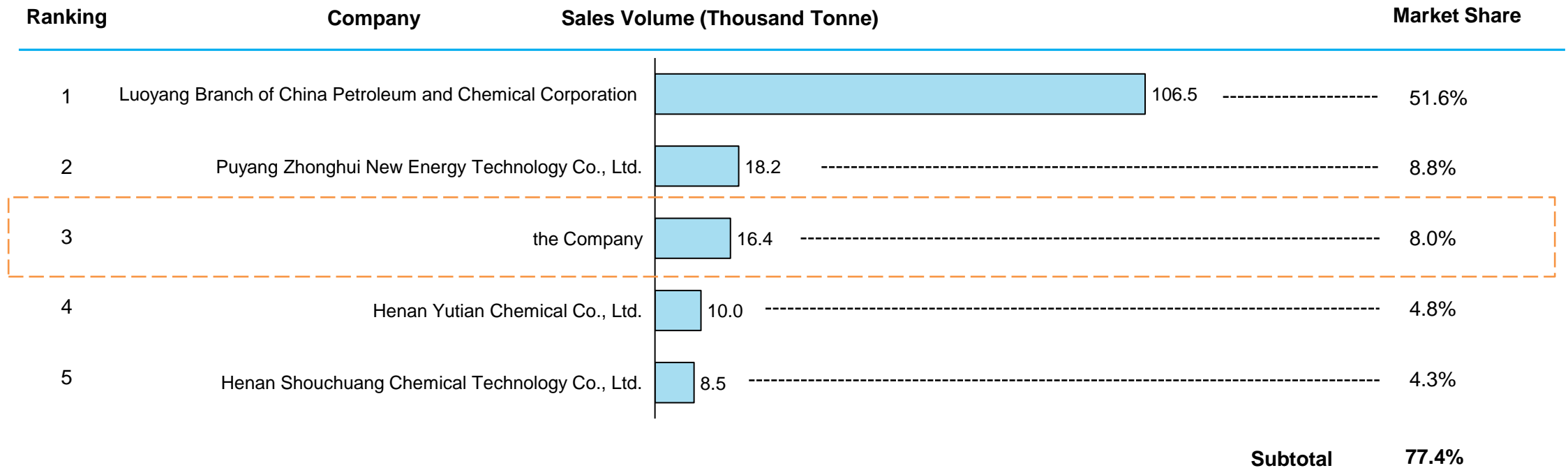


- In 2022, the market size of toluene in Henan province in terms of revenue was approximately RMB1,329.9 million, of which the top five companies accounted for about 77.5% of the total market size. In 2022, the Company's revenue of toluene was RMB106.7 million with a market share of 8.0%, ranking third in the industry.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Competitive Landscape of Henan Toluene Industry

Top Five Toluene Companies by Sales Volume (Henan Province), 2022



- In 2022, the market size of toluene in Henan province in terms of sales volume was approximately 206.3 thousand tonnes, of which the top five companies accounted for about 77.4% of the total market size. In 2022, the Company's sales volume of pure benzene was 16.4 thousand tonnes with a market share of 8.0%, ranking third in the industry.

Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China

Company Profile of Major Benzene-based Chemicals Manufacturers in Henan Province

Company Name	Year of Establishment /Headquarter	Listed/Unlisted	Business Introduction
Luoyang Branch of China Petroleum and Chemical Corporation 中国石化洛阳石化公司	1984, Luoyang, Henan Province, China	Unlisted (Parent Company has listed: SINOPEC - SH.600028)	<ul style="list-style-type: none"> Luoyang Branch of China Petrochemical Corporation (中國石化洛陽石化公司) is a super large petrochemical enterprise under China Petrochemical Corporation that integrates refining, chemical and chemical fibre. The company's production system mainly consists of three sectors: refining, chemical, and chemical fibre. In the chemical sector, the company's main products include petroleum pure benzene, petroleum toluene and other petrochemical products.
Puyang Zhonghui New Energy Technology Co., Ltd. 濮陽市中匯新能源科技有限公司	2018, Puyang, Henan Province, China	Unlisted	<ul style="list-style-type: none"> Puyang Zhonghui New Energy Technology Co., Ltd. (濮陽市中匯新能源科技有限公司) is an enterprise mainly engaged in the manufacturing of chemical raw materials and chemical products. The main products produced and sold by the company include benzene, toluene, xylene, mixed aromatics, heavy benzene, light benzene, and petroleum ether, involving research and development of new chemical materials and refined chemical products. The Company has the production capacity for hydrogenated pure benzene, hydrogenated toluene, etc.
Henan Yutian Chemical Co., Ltd. 河南宇天化工有限公司	2009, Anyang, Henan Province, China	Unlisted	<ul style="list-style-type: none"> The company is affiliated to Shuncheng Group (順成集團), a large private enterprise group integrating energy, chemicals, power generation, trade, logistics and investment. The company has the benzene hydrogenation process and has the production capacity for hydrogenated pure benzene, hydrogenated toluene, etc.
Henan Shouchuang Chemical Technology Co., Ltd. 河南省首創化工科技有限公司	2008, Xuchang, Henan Province, China	Unlisted	<ul style="list-style-type: none"> The company is a wholly-owned subsidiary of Henan Pingmei Shenma Shoushan Carbon Materials Co., Ltd. (河南平煤神馬首山碳材料有限公司). Henan Pingmei Shenma Shoushan Carbon Materials Co., Ltd. is one of the self-owned coking companies of China Pingmei Shenma Holding Group Co., Ltd. (中國平煤神馬控股集團有限公司). The company has the production capacity for hydrogenated pure benzene, hydrogenated toluene, etc.

Agenda

- 1 Overview of Macro Economic Environment
- 2 Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China
- 3 Overview of the LNG Industry in China**
- 4 Overview of the Coal Gas Industry in China
- 5 Overview of the Hydrogen Energy Industry in China
- 6 Appendix



Overview of the LNG Industry in China

Definitions and Classifications

Introduction to Natural Gas

- Natural gas is a clean fossil energy source primarily composed of alkanes, with methane making up the majority, along with smaller amounts of ethane, propane, and butane. It is primarily found in oil fields, gas fields, coal beds, and shale formations. Unconventional natural gas includes shale gas, coalbed methane, tight gas, and natural gas hydrates. Natural gas can also be categorized as pipeline natural gas (PNG), liquefied natural gas (LNG), compressed natural gas (CNG), etc.



Status of Chinese Natural Gas Industry

- While coal still dominates China's energy consumption at 56.3% in 2022, its environmental impact and unsustainability are recognized, prompting a shift towards a low-carbon economy. The country aims to curtail coal usage, improve fuel mix, and enhance eco-friendliness. Natural gas's share has grown from 7.6% in 2018 to 8.8% in 2022, as it offers cleaner and safer urban gas compared to artificial coal gas and liquefied petroleum gas. In the future, stricter environmental regulations will lead to decrease in the production of artificial coal gas. Meanwhile, China's expanding natural gas pipeline infrastructure will continue to ensure efficient distribution to end users.

Major Types of Natural Gas

Liquefied Natural Gas (LNG)

Liquefied natural gas, abbreviated as LNG, is a colourless, odourless, non-toxic and non-corrosive liquid natural gas formed by the compression and cooling of natural gas to -161.5°C . Its volume is approximately 0.16% of the same volume of natural gas, and its mass is only 45% quality of the same volume of water. Therefore, it is more flexible compared to pipeline gas transportation. Amid the context of achieving "carbon neutrality", natural gas assumes a crucial role, and the adoption of increasingly adaptable loading and transportation methods has contributed to the annual growth in LNG demand.



Pipeline Natural Gas (PNG)

Pipeline Natural Gas (PNG) transportation refers to the method of pressurizing natural gas using pipeline infrastructure for its conveyance from extraction sites or processing facilities to urban distribution centers or industrial users. Utilizing pipelines for natural gas transportation is a widespread method for land-based gas delivery. This mode of transportation offers advantages such as low costs, minimal land usage, rapid construction, high gas transport volume, enhanced safety, reduced losses during transportation, absence of emissions like "three wastes," low leakage risk, minimal environmental pollution, resilience against adverse weather conditions, low maintenance requirements, easy management, and convenient implementation of remote centralized monitoring.



Compressed Natural Gas (CNG)

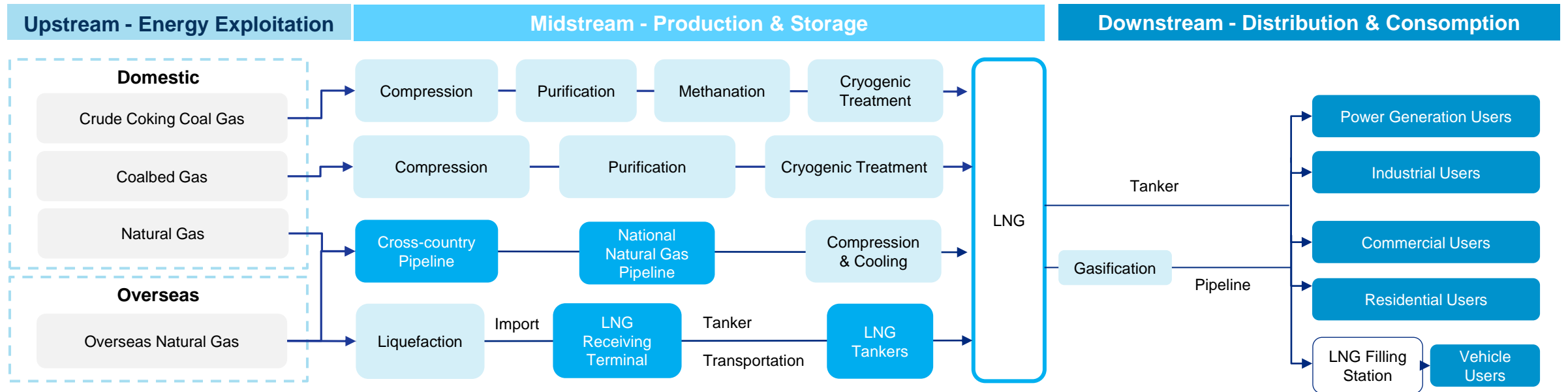
Compressed Natural Gas (CNG) refers to natural gas compressed to a pressure greater than or equal to 10MPa and not exceeding 25MPa, then deeply dehydrated under high pressure and stored in a gaseous state in containers. With the same composition as pipeline natural gas, it can be used as vehicle fuel, serving as an ideal alternative energy source for vehicles. It offers low cost, high efficiency, pollution-free characteristics, as well as convenient and safe usage, demonstrating significant development potential.



Overview of the LNG Industry in China

Value Chain Analysis

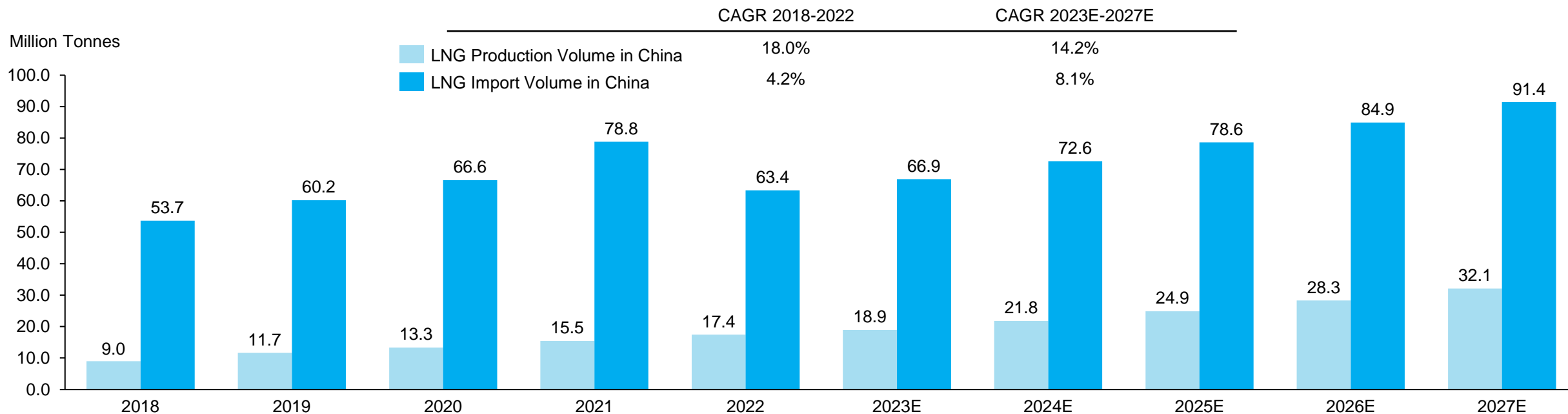
- The LNG industry mainly includes upstream energy exploitation, midstream production and storage and transportation, downstream distribution and consumption.
- International LNG importation entails entering long-term or short-term agreements with foreign suppliers and transporting overseas-produced LNG to China via specialized liquefied gas vessels. These vessels transport LNG within a liquid thermal insulation environment. Once they arrive at domestic LNG receiving stations, the LNG is stored and regasified, supplying energy for various purposes through the domestic natural gas distribution network. By integrating these two aspects, China's LNG supply ensures a consistent energy provision and also contributes significantly to the diversification of the domestic energy framework. Conversely, domestic LNG production involves converting domestically sourced natural gas into LNG for storage and conveyance. This procedure includes cooling and compressing the gas to achieve a liquid state under extremely low temperatures, followed by storage in specialized facilities and regasification into gaseous natural gas for market utilization when necessary. Simultaneously, domestic liquefied natural gas can be generated from coal. After cooling, coal-based natural gas is formed into colourless, odourless, non-toxic and non-corrosive liquid natural gas. Synthetic natural gas from coking coal gas refers to the reaction of CO, CO₂, and H₂ in coking coal gas to produce CH₄, which is then separated to obtain LNG. It has good economic benefits, is less limited by transportation distance, and is able to meet the growing energy demand with broad development prospects.
- LNG can directly enter the domestic natural gas pipeline through gasification to transport to large industrial customers and the local distribution network. In addition, LNG can also be transported to downstream customers through tankers. Natural gas is generally transported to provincial natural gas enterprises and then to local natural gas enterprises through city gateway stations. Local natural gas enterprises reduce the pressure and add odor to the natural gas (for easy leakage detection), and then transport natural gas to industrial, commercial, residential, gas stations and other customers through small low-pressure pipelines.



Overview of the LNG Industry in China

Production and Import Volume of LNG - China

Production and Import Volume of LNG (China), 2018-2027E

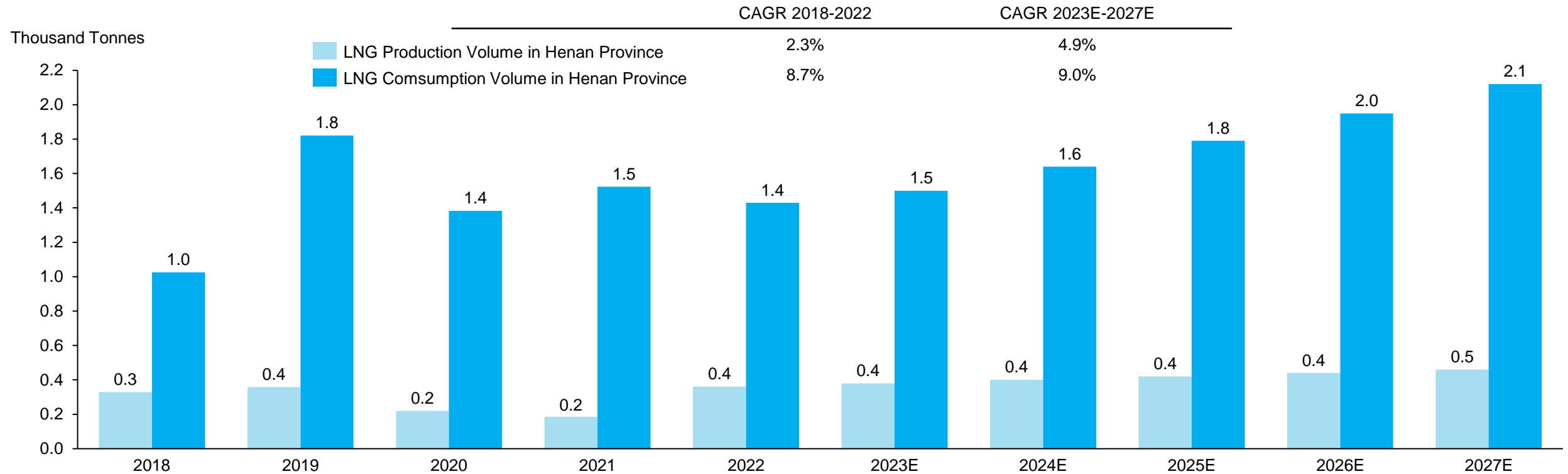


- LNG’s production in China increased from 9.0 million tonnes in 2018 to 17.4 million tonnes in 2022, representing a CAGR of 18.0% from 2018 to 2022. Currently, the “national network” (“全國一張網”) has been largely established, leading to a significant improvement in natural gas interconnection capacity. Furthermore, there has been a continuous enhancement in gas storage and peak shaving capacity. It is expected that the LNG production in China will reach 32.1 million tonnes by 2027, with a CAGR of 14.2% from 2023.
- China’s natural gas production is insufficient to meet the rapidly growing consumption demand, which in turn stimulates the demand for natural gas imports. China’s major LNG import countries include Australia, the U.S., Qatar, Malaysia, Indonesia and other countries. China’s natural gas imports increased at a CAGR of 4.2% from 53.7 million tonnes in 2018 to 63.4 million tonnes in 2022. Currently, China’s energy industry is in the process of transforming from heavily dependent on coal economy to a diversified energy economy. Natural gas will play an important role in China’s future energy supply. It is expected that China will continue to rely on overseas natural gas supply, and China’s LNG import will increase to 91.4 million tonnes by 2027, representing a CAGR of 8.1% from 2023 to 2027.

Overview of the LNG Industry in China

Production and Consumption Volume of LNG - Henan Province

Production and Consumption Volume of LNG (Henan Province), 2018-2027E



• Being a province characterized by substantial energy consumption, Henan province has witnessed a consistent rise in LNG consumption over recent years. The consumption has escalated from 1.0 million tonnes in 2018 to 1.4 million tonnes in 2022, reflecting a CAGR of 8.7% throughout this period. Meanwhile, LNG production in Henan province increased from 0.3 million tonnes in 2018 to 0.4 million tonnes in 2022, representing a CAGR of 2.3% during the period. In 2022, over 70% of the consumption of LNG was dependent on the supply from other provinces and imported LNG. With the upgrade of energy structure in Henan province, the consumption of LNG in Henan province is expected to further increase from 1.5 million tonnes in 2023 to 2.1 million tonnes in 2027, representing a CAGR of 9.0% during the period. By 2027, LNG's production in Henan province is expected to reach 0.5 million tonnes, representing a CAGR of 4.9% from 2023 to 2027.

Overview of the LNG Industry in China

Market Drivers and Developing Trends Analysis (1/2)

Proportion of natural gas in the energy mix is expected to further increase

- ✓ China is projected to raise its natural gas share in the energy mix, driven by government policies that support the industry. The “Energy Production and Consumption Revolution Strategy (2016-2030)” (《能源生產和消費革命戰略(2016-2030)》) outlines a goal for natural gas to comprise 15% of China’s energy consumption by 2030. This will decrease coal reliance and boost natural gas use. Despite domestic production constraints, China is increasing its natural gas imports to meet growing demand. In Henan province, with its large population and energy consumption, natural gas demand is increasing, prompting the need for a diverse supply system. In terms of regional policies, Henan’s “14th Five-Year” Plan (《河南省人民政府關於印發河南省「十四五」現代能源體系和碳達峰碳中和規劃的通知》) also focuses on substituting high-carbon fuels like coal with low-carbon alternatives, particularly natural gas.

Favourable policies support coal coking natural gas development

- ✓ The implementation of favourable policies, like the “14th Five-Year Development Plan for the Coking Industry” (《焦化行業「十四五」發展規劃綱要》), has greatly boosted coal-based coking natural gas growth. This plan emphasizes circular economy benefits in coking parks, fostering an environment for coal-based coking natural gas advancement. The government is also promoting collaboration among coking parks for ecological industrial network enhancement. This initiative aims to achieve “zero emissions” in coking parks and establish a well-balanced resource recycling system. Additionally, the government advocates extending the coal coking industry to downstream and fine chemical products, enhancing product value. Overall, these policies will drive sustainable development in the coal-based coking natural gas sector.

Rise in natural gas vehicles drives LNG demand

- ✓ Natural gas vehicles, as vehicles that use natural gas as fuel, are characterised by low emissions and are environmentally friendly. The fuel storage of gas vehicles mainly uses natural gas or compressed natural gas, of which compressed natural gas for vehicles is compressed to around 20-25 MPa. Natural gas is compressed and extracted through water removal, desulfurisation and purification, and then supplied to vehicles through high-pressure cylindrical gas cylinders. The ignition principle of natural gas vehicles is similar to that of gasoline vehicles. The natural gas is depressurised by a pressure regulator and mixed with air in a mixer. Sensors and computers regulate the mixture to achieve more efficient combustion. Natural gas then enters the cylinder through a multi-point injection rail and is ignited by a spark plug. According to the data from the China Association of Automobile Manufacturers, the sales volume of commercial natural gas vehicles in China from January to June 2023 was 70,222 units, representing a year-on-year increase of 223.7%. In the future, with the increase in the number of natural gas vehicles, the demand for LNG will further increase.

Overview of the LNG Industry in China

Market Drivers and Developing Trends Analysis (2/2)

Improving LNG storage and transportation capacity

- The increasing capacity of LNG in storage and transportation drives the development of the LNG market. In the industry chain of LNG, the storage and transportation sector play an important role, connecting the upstream and downstream sectors closely. In China, LNG's transportation methods mainly include pipeline transportation, shipping transportation and low-temperature LNG tanker transportation. As the nationwide promotion of natural gas gains momentum and the role of LNG strengthens within the realms of natural gas trade and utilisation, the forthcoming surge in LNG transportation is poised to swiftly propel the growth of the LNG market. The improvement of LNG storage and transportation capacity, including the economic advantages of using large-capacity tankers and gas tanks, and railway tanker transportation, plays a positive role in the LNG market. This will enhance the efficiency and reliability of the LNG supply chain and provide strong support for the promotion and application of LNG.

Accelerating natural gas market reform driven by increased private sector competition

- In the past, the natural gas market in China has adopted a point-to-point trading model with complicated pipeline transmission costs, which hindered the formation of a unified competitive market. In recent years, the PRC government has taken measures to accelerate market-oriented reforms. The establishment of PipeChina has promoted the liberalisation of gas prices and market-oriented resource allocation, which promoted market-oriented pricing. The 14th Five-Year Plan for Modern Energy System (《「十四五」現代能源體系規劃》) emphasises the promotion of market-oriented reform of natural gas prices and the reduction of gas distribution levels. Driven by policies, China's natural gas market-oriented reform will be further implemented and become one of the development trends of the industry. The market-oriented pricing mechanism will promote the optimisation of resource allocation and industry development. Private enterprises can participate in the market through competition, supply more natural gas and offer more services, thus promoting a health development of the industry.

LNG industry moving towards intelligent development

- With advanced technology, the LNG sector has achieved intelligent management across production, storage, transportation, and consumption. These technologies enhance efficiency, safety, and sustainability, driving the industry's smart and efficient growth. In production, automation, sensors, and intelligent monitoring ensure real-time adjustments, boosting efficiency. Smart storage, pipelines, and vessels utilise sensors for real-time monitoring of parameters like temperature and pressure, ensuring safe transportation. Data collection and analysis, along with AI, are increasingly important, enabling real-time monitoring and improved efficiency, energy savings, and emissions reduction.

Overview of the LNG Industry in China

Entry Barrier Analysis

Compliance barriers

- The compliance barrier of China's LNG market encompasses technology, environment, energy consumption, product quality and social responsibility. Enterprises must meet the technical requirements, master the LNG process and equipment, and possess the corresponding skills. Secondly, enterprises are required to comply with environmental protection requirements, adopt effective measures to reduce their impact on the environment and ensure safe production. In addition, ensuring the quality of LNG is critical to the stable and safe supply of energy, and enterprises need to ensure that their products meet relevant quality standards and specifications. To compete in the LNG industry, new market entrants should have technical capabilities and resources, comply with industry norms and self-discipline conventions, and prioritise environmental protection, energy utilisation and product quality.

Capital barriers

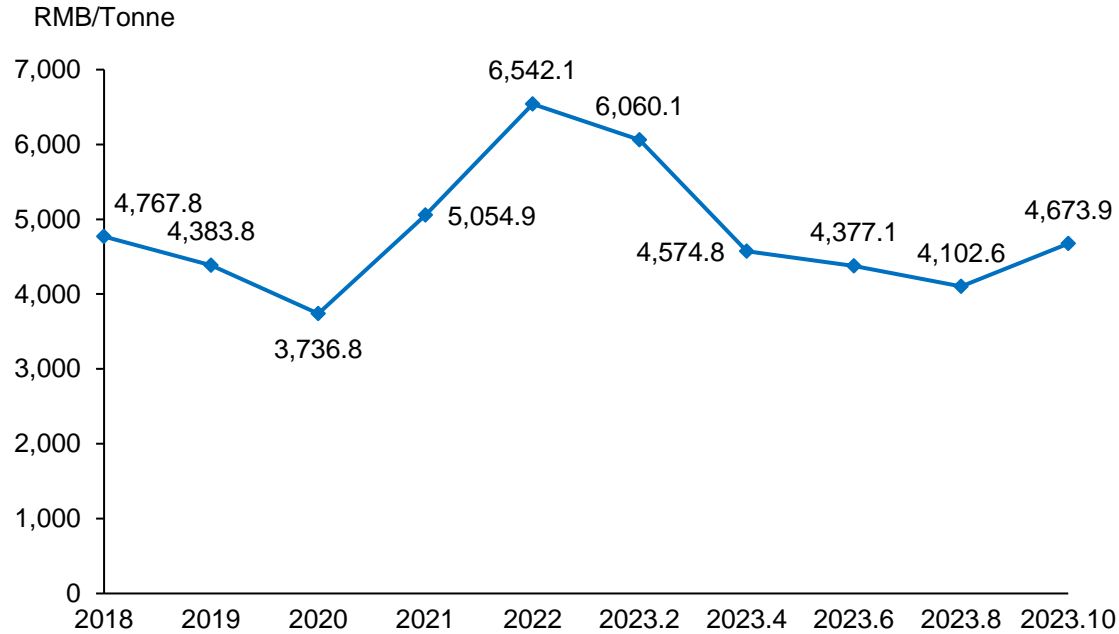
- LNG project requires substantial capital investment. Firstly, the construction of production facilities, storage and transportation equipment and ancillary facilities are supported by substantial capital. Secondly, a sound supply chain system also requires large-scale capital investment to ensure reliable supply and stable transportation. Additionally, technological research and development and innovation also require capital injection to improve efficiency, process flow, and enhance energy efficiency and environmental friendliness. New entrants need to have strong financial strength to meet the needs of project construction, operation and technological innovation.

Source: Frost & Sullivan

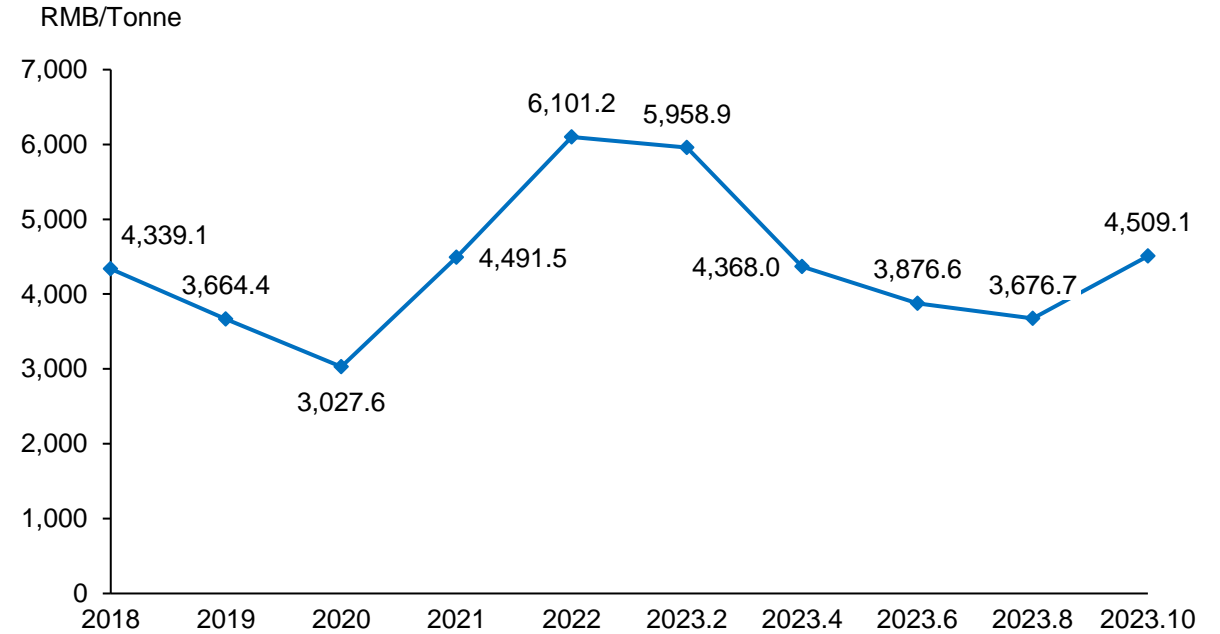
Overview of the LNG Industry in China

LNG Price Analysis

Retail Price of LNG for Vehicles at Gas Stations (Henan Province), 2018-2023.10



Ex-Factory Price of LNG (Henan Province), 2018-2023.10



- The LNG retail price and ex-factory price are not subject to any government pricing guidelines. Due to the fluctuation in demand for natural gas, the retail price of LNG for vehicles at gas stations in Henan province decreased from RMB4,767.8/tonne in 2018 to RMB3,736.8/tonne in 2020. In 2022, after the outbreak of Russia and Ukraine geopolitical conflict, Russia reduced its pipeline natural gas exports to Europe in response to Western sanctions imposed over the conflict between Russia and Ukraine. As a result, the geopolitical conflict has significantly increased the uncertainties of global natural gas supply, driving up the international natural gas prices. Affected by the rising international natural gas prices, the retail price of LNG for vehicles at gas stations in 2022 in Henan Province reached the peak of RMB6,542.1/tonne in recent years. Since the start of 2023, attributed to the unusually warm winter weather observed in the northern hemisphere, the prominent global markets for natural gas consumption did not attain the anticipated growth of demand, preventing the international natural gas prices from further increasing. The retail price of LNG for vehicles at gas stations in Henan province declined gradually from the peak in 2022. Since September 2023, driven by the recovering international natural gas prices, the retail price of LNG for vehicles at gas stations in Henan province has presented an upward trend, reaching RMB4,673.9/tonne in October 2023.
- The ex-factory price of LNG in Henan province is in line with the retail price trend of LNG for vehicles at gas stations, of which the ex-factory price of LNG in 2018 was RMB4,339.1/tonne, and its price recovered to RMB6,101.2/tonne in 2022 after hitting a low of RMB3,027.6/tonne in 2020. Similarly, the ex-factory price of LNG in Henan province recovered from the peak in 2022 and has rebounded since September 2023, reaching RMB4,509.1/tonne in October 2023.

Note: The price above is excluding VAT.

Overview of the LNG Industry in China

LNG Price Analysis

- As Europe will continue to import LNG to make up for the decrease in Russian pipeline natural gas, and it will take time for the newly added global LNG production capacity to ramp up, global LNG supply and demand will remain relatively tightly balanced in the next 2 to 3 years, which is expected to support the recovery of global LNG prices. Meanwhile, driven by the carbon neutrality goal, the proportion of natural gas in overall energy consumption will continue to increase, thereby driving up the market demand for LNG. According to the Henry Hub natural gas futures on the New York Mercantile Exchange, which is a widely recognized natural gas futures market in the world and a commonly used indicator for price trend, international natural gas prices are expected to remain relatively stable or keep a steady increase in the near future. Since China is highly dependent on LNG imports, global LNG price fluctuations will be transmitted to China. Therefore, it is expected that China's LNG prices will remain a similar trend as the international LNG prices in the near future.

Overview of the LNG Industry In China

Competitive Landscape

Top Five LNG Suppliers by Revenue (Henan Province), 2022

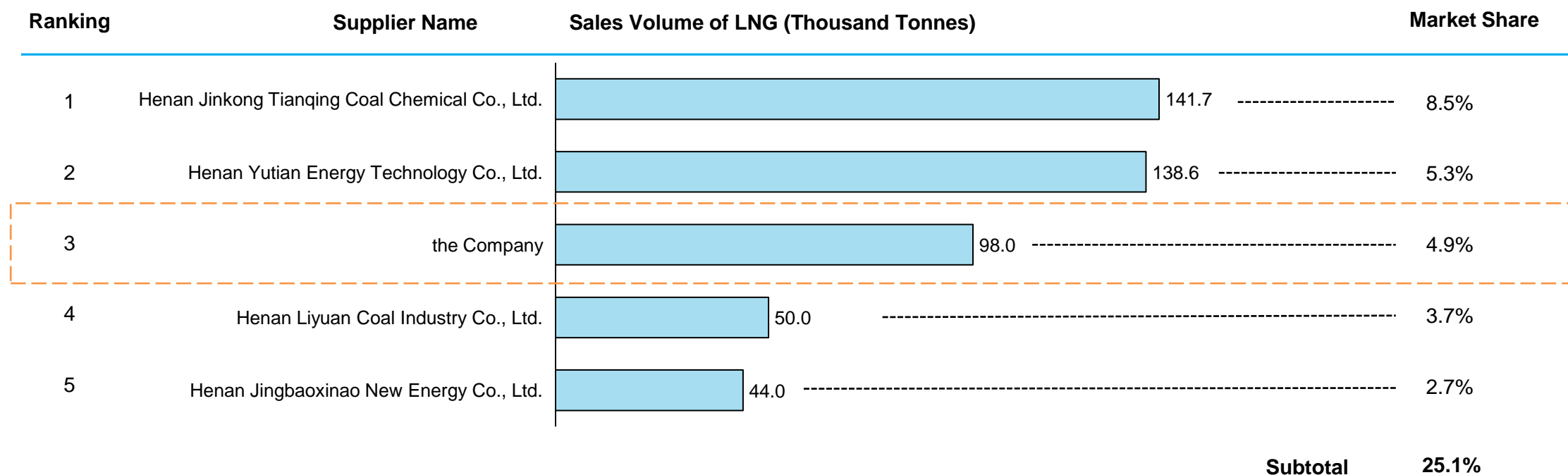
Ranking	Supplier Name	Revenue of LNG (RMB Million)	Market Share
1	Henan Jinkong Tianqing Coal Chemical Co., Ltd.	736.9	8.4%
2	Henan Yutian Energy Technology Co., Ltd.	462.1	5.3%
3	the Company	428.2	4.9%
4	Henan Liyuan Coal Industry Co., Ltd.	325.4	3.7%
5	Henan Jingbaoxinao New Energy Co., Ltd.	233.7	2.7%
Subtotal			25.1%

- The top five LNG suppliers in Henan province in terms of revenue accounted for approximately 25.1% of the total market size. In 2022, the Company's LNG achieved a revenue of RMB428.2 million, accounting for 4.9% of the market share and ranking third amongst all LNG suppliers in Henan Province.

Overview of the LNG Industry In China

Competitive Landscape

Top Five LNG Suppliers by Sales Volume (Henan Province), 2022



- The top five LNG suppliers in Henan province in terms of sales volume accounted for approximately 25.1% of the total market size. In 2022, the Company's LNG achieved a sales volume of 69.8 thousand tonnes, accounting for 4.9% of the market share and ranking third amongst all LNG suppliers in Henan Province.

Overview of the LNG Industry in China

Company Profile of Major LNG Manufacturers in Henan Province

Year of Establishment /Headquarter	Listed/Unlisted	Business Introduction	Year of Establishment /Headquarter
Henan Jinkong Tianqing Coal Chemical Co., Ltd. 河南晋控天庆煤化工有限责任公司	2010, Jiaozuo, Henan Province, China	Unlisted	<ul style="list-style-type: none"> Henan Jinkong Tianqing Coal Chemical Co., Ltd. (河南晋控天庆煤化工有限责任公司) (hereinafter referred to as "Jinkong Tianqing Company") is a large-scale modern new coal chemical company with clean energy, chemical fertilisers and chemicals as its main products, and is mainly engaged in the production and sales of chemical fertilisers such as coal-based gas, synthetic ammonia and urea. The company is a wholly-owned subsidiary of Shanxi Jincheng Anthracite Coal Mining Group Co., Ltd. (山西晋城无烟煤矿业集团有限责任公司) (hereinafter referred to as "Jinmei Group"), which is a large state-owned energy enterprise group controlled by Shanxi SASAC.
Henan Yutian Energy Technology Co., Ltd. 河南宇天能源科技有限公司	2014, Anyang, Henan Province, China	Unlisted	<ul style="list-style-type: none"> Henan Yutian Energy Technology Co., Ltd. (河南宇天能源科技有限公司) is a joint venture of Henan Shuncheng Group Coking Co., Ltd. (河南省顺成集团煤焦有限公司) and Henan Yutian Chemical Co., Ltd. (河南宇天化工有限公司). The business scope of the company includes: gas operation; gas refuelling operations for gas vehicles; power generation, transmission, supply and distribution; power supply business; production of hazardous chemicals, etc. Henan Shuncheng Group Coking Co., Ltd. (河南省顺成集团煤焦有限公司) is a large private enterprise group integrating energy, chemical, power generation, trading, logistics and investment.
Henan Liyuan Coal Industry Co., Ltd. 河南利源煤业有限公司	2004, Anyang, Henan Province, China	Unlisted	<ul style="list-style-type: none"> The company is a major coal chemical enterprise in Henan Province. The company has formed a relatively complete circular economy industrial chain such as clean gas and oil products, fine chemicals, new chemicals, new materials, hydrogen energy, etc.
Henan Jingbaoxinao New Energy Co., Ltd. 河南京宝新奥新能源有限公司	2011, Pingdingshan, Henan Province, China	Unlisted	<ul style="list-style-type: none"> The company is a joint venture between China Pingmei Shenma Holding Group Co., Ltd. (中国平煤神马控股集团集团有限公司) and ENN Energy Holdings Co., Ltd. (新奥能源控股有限公司). The company uses crude coking coal gas as raw material to produce LNG.

Agenda

- 1 Overview of Macro Economic Environment
- 2 Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China
- 3 Overview of the LNG Industry in China
- 4 Overview of the Coal Gas Industry in China**
- 5 Overview of the Hydrogen Energy Industry in China
- 6 Appendix



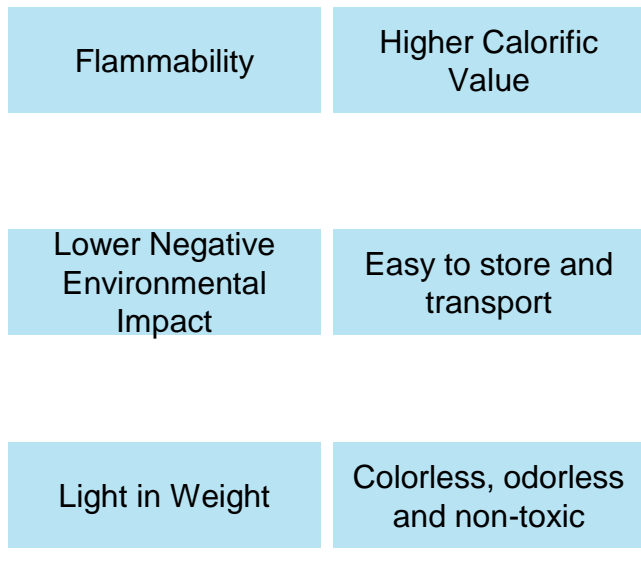
Overview of the Coal Gas Industry in China

Overview of Coal Gas Industry

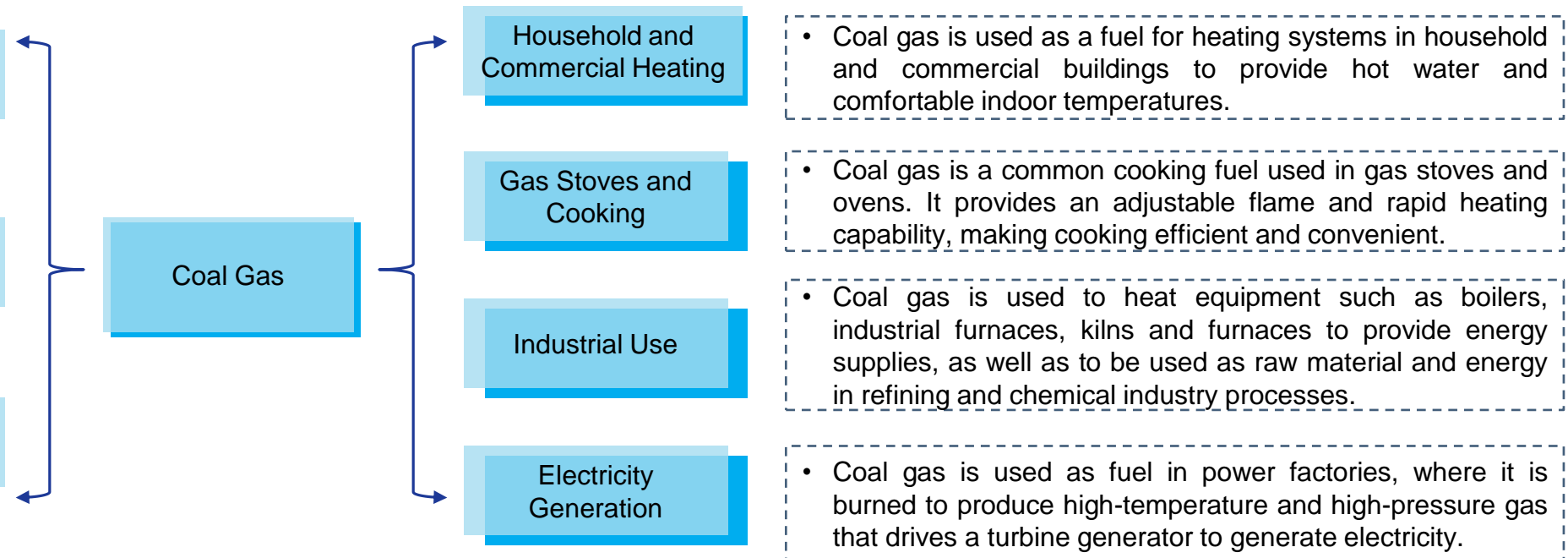
Definition

- Coal gas can be obtained through the purification process of crude coking coal gas produced in the coking process and is extracted through the purification process of recovering crude benzene, coal tar, sulphur and ammonia. Coal gas is mainly used as city household fuel or industrial fuel, and carbon monoxide, hydrogen gas and methane in coal gas are important chemical raw materials. In terms of major components, coal gas typically consists of approximately 57.0% of hydrogen gas, 26.0% of methane, 8.0% of carbon monoxide and 2.0% of carbon dioxide, etc.

Characteristic

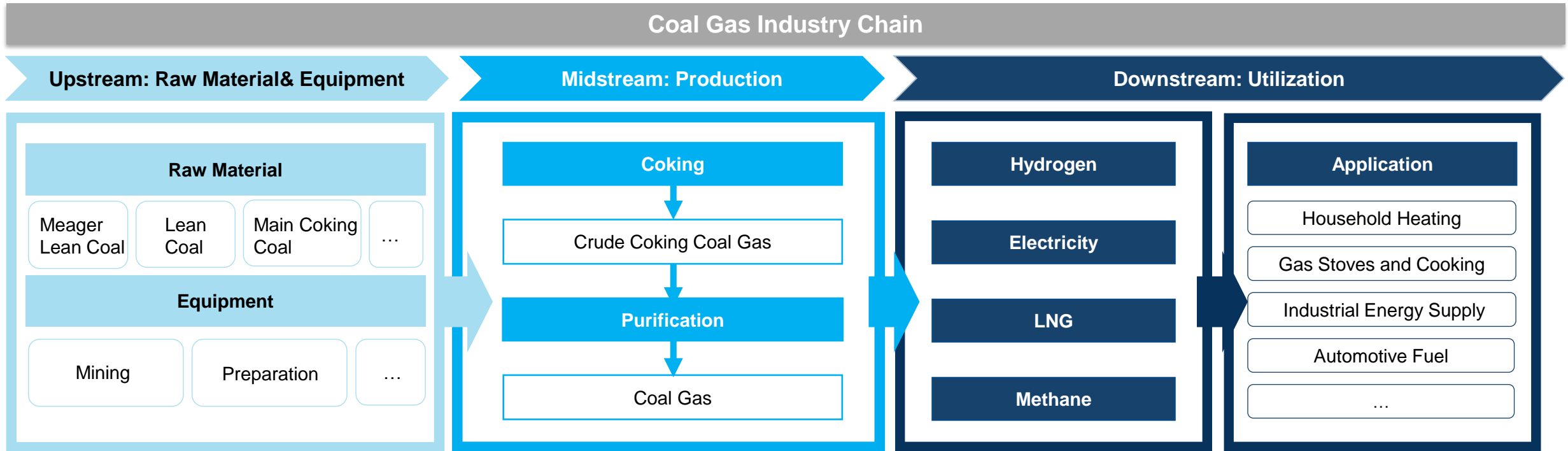


Major Application Scenario



Overview of the Coal Gas Industry in China

Analysis of Coal Gas Industry Chain

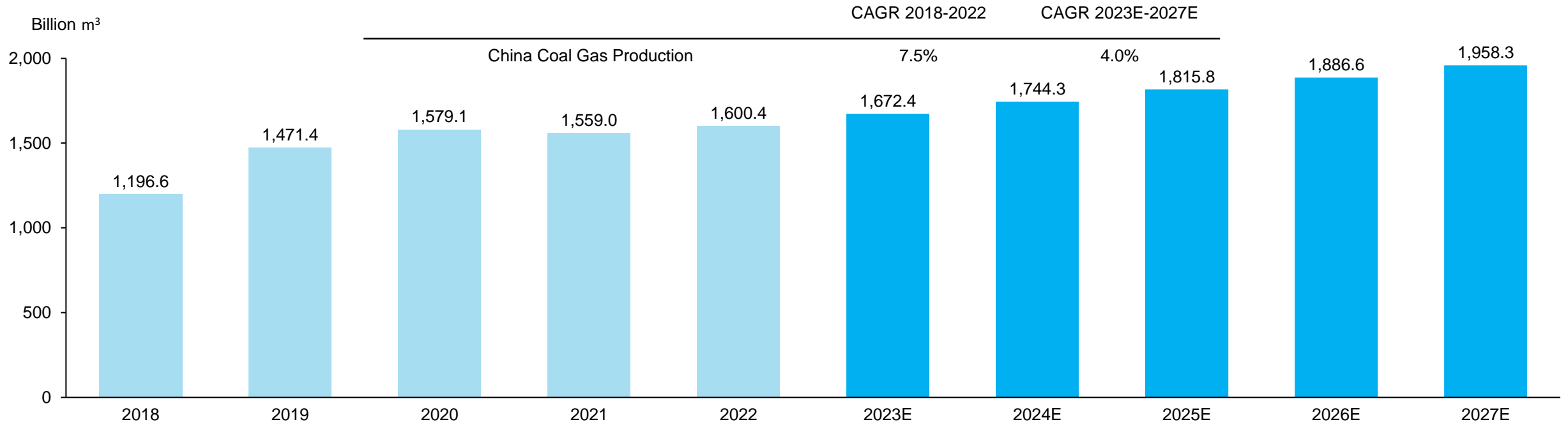


- Coal gas has become one of the most important secondary energy sources since the 21st century. The industry of coal gas covers all aspects from mining to final use of coal resources. As the starting process in the chain, coal mining usually involves exploration, drilling, selective picking and other operations to search for and extract coal resources. The midstream of the coal gas industry is mainly the production of coal gas. Coking is the process of distilling different types of coking coal mixtures at high temperature under insulated air conditions to concentrate the carbon content of coal. The crude coking coal gas from coking furnace is cooled and treated with various absorbents to obtain purified coal gas. The downstream of the coal gas industry is the use of coal gas to extract hydrogen gas, produce liquefied natural gas, generate electricity and produce methane, etc. Coal gas is ultimately used for household heating and hot water, industrial energy supply, etc.

Overview of the Coal Gas Industry in China

Production Volume of Coal Gas—China

Production Volume of Coal Gas (China), 2018 – 2027E



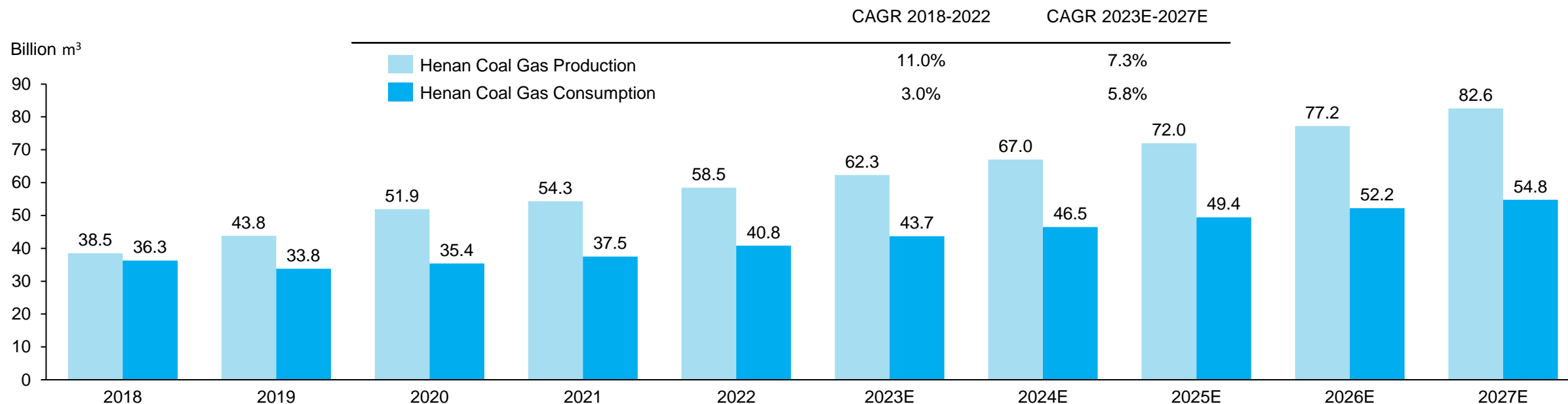
- With its widely distributed coal resources, China has become a major producer of coal gas. In addition, the large population base and the fast-growing economy also provide a guarantee for the stable demand of the coal gas market. Production volume of coal gas in China increased from 1,196.6 billion m³ in 2018 to 1,600.4 billion m³ in 2022, representing a CAGR of 7.5% during the period. Looking ahead, production volume of coal gas in China is expected to increase from 1,627.4 billion m³ in 2023 to 1,958.3 billion m³ in 2027, representing a CAGR of 4.0% during the period.

Source: (1) Frost & Sullivan Report, (2) National Bureau of Statistics, and (3) Interviews with industry experts by Frost & Sullivan

Overview of the Coal Gas Industry in China

Production and Consumption Volume of Coal Gas—Henan Province

Production and Consumption Volume of Coal Gas (Henan Province), 2018 – 2027E



- A number of large coal mines and coal fields in Henan province support the stable supply of coal gas. From 2018 to 2022, production volume of coal gas in Henan province increased from 38.5 billion m³ to 58.5 billion m³, representing a CAGR of 11.0% during the period. In addition, the strong development of industrial sectors in Henan province, such as energy, chemicals and metallurgy, also contributes to the growth of demand for coal gas in the province. The consumption volume of coal gas in Henan province increased from 36.3 billion m³ in 2018 to 40.8 billion m³ in 2022, representing a CAGR of 3.0% during the period. It is expected that by 2027, the production and consumption volume of coal gas in Henan province will reach 82.6 and 54.8 billion m³, respectively. In the past, the coal gas generated during the coking process was not fully used, and some of which were discharged into the atmosphere. Currently, with the increasing awareness of energy conservation and environmental protection among coking enterprises, the utilisation of coal gas has been further optimised, and the coal gas produced has been recycled or further processed into high value-added products such as hydrogen gas and LNG to improve overall operating profitability

Note: The consumption volume of coal gas in Henan province refers to the end consumption volume of coal gas, which excludes the self-consumed volume of the coal gas manufacturing factories.

Source: (1) Frost & Sullivan Report, (2) National Bureau of Statistics, (3) China Energy Statistical Yearbook, and (4) Interviews with industry experts by Frost & Sullivan.

Overview of the Coal Gas Industry in China

Analysis of Coal Gas Market Drivers and Trends

Supportive policy

- With the progress of the industry and the guidance of national policies, China's coal gas industry is gradually developing towards the direction of environmental protection, low-carbon and energy conservation. In April 2022, the Ministry of Ecology and Environment of the PRC issued the "Implementation Plan for Environmental Impact Assessment and Pollutant Discharge Permits during the 14th Five-Year Plan period" (《「十四五」環境影響評價與排污許可工作實施方案》), which stated strictly implementation of capacity substitution and reduction measures in the environmental assessment and approval of steel, coking and other industrial projects in key areas. The standardised coal gas industry driven by policies will ensure the safe, environmentally friendly, high-quality and reliable supply of coal gas and promote the sustainable development of the industry.

Stable development of the coking industry

- As a high-temperature reducing agent and fuel, coke provides important raw materials for metallurgy, chemicals, construction materials and other industries. Through the introduction of advanced coking furnace technology and environment-friendly equipment, the production capacity and quality of coking have been improved while reducing the negative impact on the environment. The continuous adjustment and optimisation of China's energy structure has continuously improved the energy utilisation efficiency and environmental protection of the coking industry.

The utilisation efficiency of coal gas will be further improved

- Recently, the recycling of coal gas has received increasing attention, and the comprehensive recycling is in line with China's industrial policies focusing on energy conservation strategies. In the future, coking enterprises are expected to increase their efforts in exploring the potential of coal gas utilisation, such as the production of refined chemical products or coal gas through the processing of coking by-products from recycling and reuse. Through the configuration of advanced equipment and the development of new technologies, the utilisation efficiency of coal gas will be gradually improved.

Environmental protection requirements promote the conversion of coal gas into low carbon energy such as hydrogen gas

- As coal processing generates a large amount of waste water and waste gas, industries related to coal have been regarded as industries with high energy consumption and heavy pollution. Under the call of using low carbon energy and protecting the environment, many enterprises, especially small and medium-sized enterprises, have to eliminate backward production capacity. Under such circumstances, the coal gas industry will pay more attention to the conversion of coal gas into other low carbon energy such as hydrogen gas, so as to meet the requirements of environmental protection and energy conservation as well as to improve the level of energy utilisation.

Overview of the Coal Gas Industry in China

Analysis of Barriers to Enter into the Coal Gas Industry

Concession Barrier

- In order to improve the operational efficiency of municipal public utilities, China has established a nationwide concession system for public utilities. The “Measures for the Management of Urban Gas in Henan province” (《河南省城鎮燃氣管理辦法》), issued by the Henan government, stipulated that relevant gas authorities shall screen pipeline gas investment or operation enterprises through competition mechanism such as bidding and tendering, and sign a concession agreement in accordance with the provisions. Leading coal gas enterprises with advanced technology, operation and management experience as well as strong capital have a competitive advantage in the market competition, thus obtaining long-term stable concession rights and forming market dependency.

Technology Barrier

- Coal gas production involves a series of technologies and production processes that have a significant impact on production, quality and safety of coal gas. Established coal gas enterprises have undergone a lengthy development process to improve production and processing techniques and develop and introduce supporting technologies. New entrants may struggle to master such technologies and processes in a short term due to limited time and resources.

Capital Barrier

- Due to the relatively long construction period and the high procurement cost of plant and equipment, the coal gas industry requires more capital than other industries, especially at the start-up stage. In addition, substantial capital is needed for the R&D and innovation in key technologies related to extraction, processing, conversion and utilisation of coal gas, including equipment procurement, laboratory construction and talent training. New entrants need sufficient capital strength to overcome capital barriers.

Emission Control Barrier

- In November 2021, the State Council issued the “Opinions on Deepening the Fight Against Pollution Prevention and Control” (《關於深入打好污染防治攻堅戰的意見》), which stated that the scale of coal-to-oil and gas production capacity should be reasonably controlled. Due to increasingly stringent emission control standards, certain existing coking enterprises, especially small- and medium-sized enterprises, must shut down production capacity to meet emission requirements. New entrants may struggle to meet the emission standards set by the Chinese government and may not obtain government approval for production.

Overview of the Coal Gas Industry in China

Analysis of Market Opportunities and Challenges in Coal Gas Industry

The coking industry is facing challenges under the “Carbon Peak” and “Carbon Neutrality”

The traditional coking production takes coking coal as raw material, gas as fuel, coke as product and coal gas as by-product, which generates a large amount of pollutants and belongs to the industry of high energy consumption and high emission. Therefore, in the context of China’s “carbon peak” and “carbon neutrality”, the coking industry is facing great pressure to reduce emissions. In the short term, the approval of new projects in the coking industry will be more difficult, and the requirements for reducing energy consumption and coal consumption will be increased; In the long run, the demand for coke in the downstream coking industry is also likely to decline. The traditional coking industry needs to use advanced technology and equipment to improve energy efficiency and find its own low-carbon way out.

The energy efficiency benchmark level puts forward requirements for energy consumption in the industry

In November 2021, the National Development and Reform Commission and other departments issued the Energy Efficiency Benchmark Level and Benchmark Level in Key areas of high Energy consumption Industries(《高耗能行業重點領域能效標杆水準和基準水準》), requiring that the proposed projects and projects under construction should reach the energy efficiency benchmark level, and the stock projects with energy efficiency lower than the benchmark level should set a transition period. In February 2022, the "Implementation Guide for Energy Conservation and Carbon Reduction Transformation and Upgrading of Modern Coal Chemical Industry" (《現代煤化工行業節能降碳改造升級實施指南》) proposed to actively promote this implementation guide and green technology promotion directory for enterprises whose energy efficiency is below the benchmark level. This puts higher requirements on the energy consumption of the coking industry, and promotes the improvement of the green level of its production process and technical equipment. The improvement of resource utilization efficiency will help promote the growth of the domestic market.

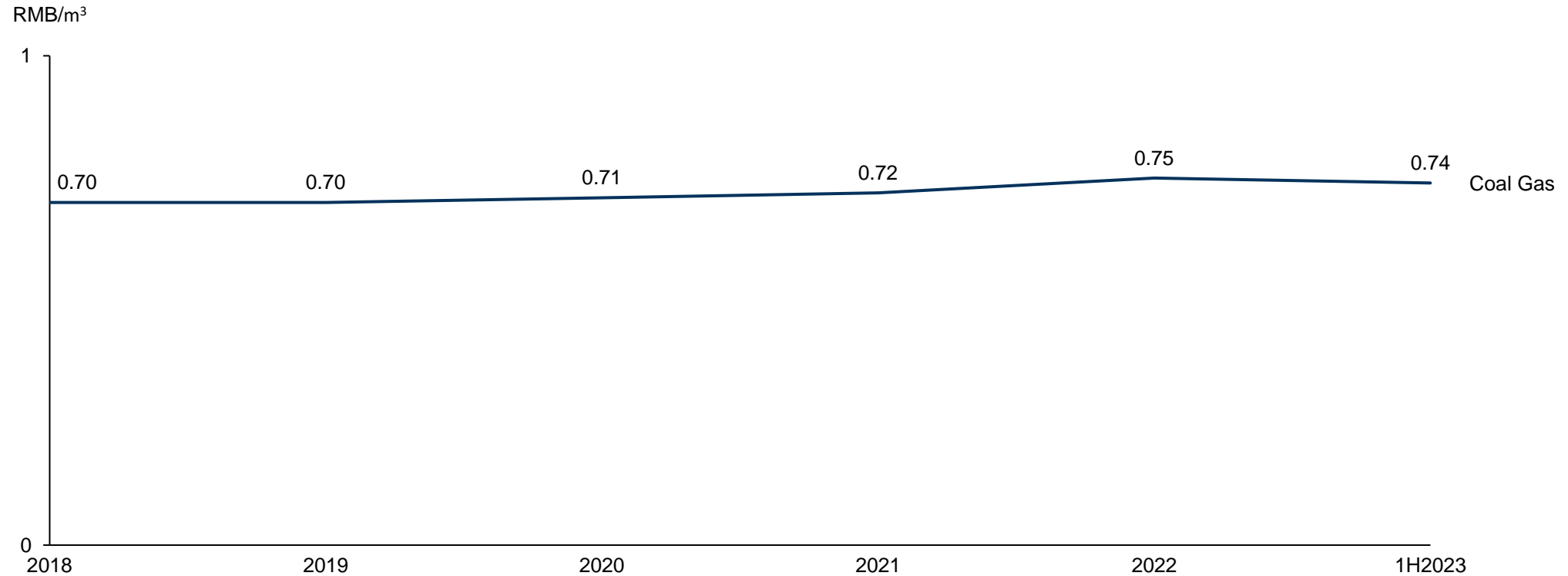
The level of intelligent manufacturing is in line with international standards

Under the requirements of green transformation development, the coking industry has accelerated the pace of eliminating backward production capacity and introducing advanced process technology and production equipment. Advanced gas related enterprises will make full use of the innovative resources of institutions of higher learning, research institutes to promote the key technologies of energy conservation, pollution reduction and carbon reduction synergies, as well as cutting-edge leading technologies and related facilities and equipment, promoting the high-quality development of the industry. It is expected that in the future, the gas industry will form an efficient comprehensive utilization technology with high technology efficiency, device integration and automation, and the gap between its intelligent manufacturing level and that of foreign enterprises will gradually narrow.

Overview of the Coal Gas Industry in China

Price Analysis of Coal Gas

Prices of Coal Gas (Henan Province), 2018 –1H2023



- Since crude coking coal gas, which is one of the coking by-products of the coking process, needs to be delivered through pipelines, most crude coking coal gas producers often give priority to 1) self-use, followed by 2) sell to nearby subsidiaries for further processing. Therefore, the crude coking coal gas market is relatively closed, and the price mainly reflects the internal selling price within a group. The price of crude coking coal gas in Henan province in general ranged from RMB0.4-0.6/m³ with an increasing trend during 2020-2022 and 1H2023. Meanwhile, in order to promote the sustainable development of the coal gas market and ensure the fundamental gas demand of residential and industrial users, the price of processed coal gas in Henan province also remained relatively stable.

Note: The price in the chart refers to the ex-factory price of coking coal gas. The price above is excluding VAT.

Overview of the Coal Gas Industry in China

Pricing Methodology on Coal Gas

- As for the pricing method of gas, the Regulations on the Administration of Urban Gas (《城鎮燃氣管理條例》) stipulate that the selling price of gas shall be reasonably determined and adjusted in a timely manner on the basis of the cost of gas, operating cost and the level of local economic and social development. The price administrative authority of the local people's government at or above the county level shall seek the opinions of the users of piped gas, the operators of piped gas and the relevant parties when determining and adjusting the selling price of piped gas.

Competitive Landscape of the Coal Gas Market in Henan Province and Jiyuan City

- Since the crude coking coal gas market is relatively closed and companies mainly use coal gas for their own production and sell to nearby subsidiaries, there is no specific competition among different companies in Henan Province.
- The current concession agreement Jinning Energy entered into with the local government of Jiyuan city, whereby Jinning Energy was granted the exclusive right to transport coal gas to the industrial enterprises and residential users in the vicinity of Huancheng Road (環城路) and the residents of Du Village (杜村) in Chengliu town (承留鎮), Jiyuan city, is valid until April 2033. Therefore, there is no direct competitor within the operating area of the concession agreement.

Agenda

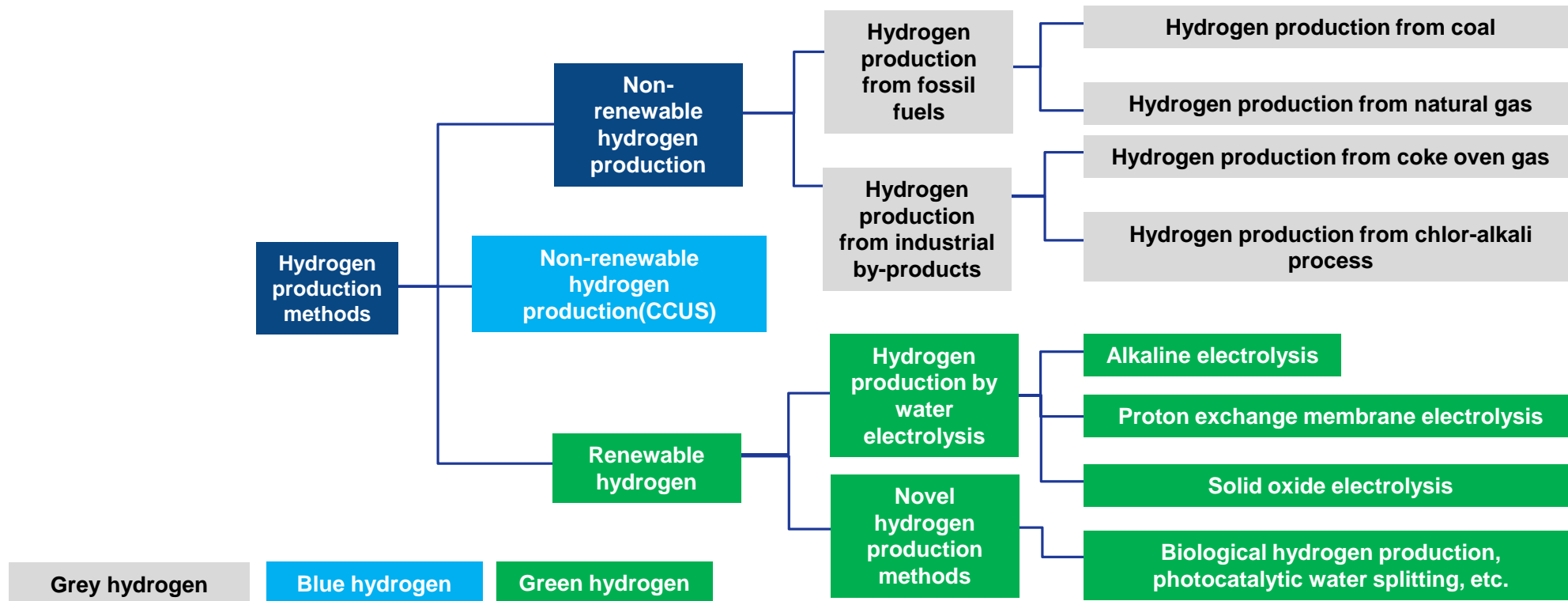
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Overview of the Hydrogen Industry in China

Definition of Hydrogen Gas and Analysis of Hydrogen Production Methods (1/2)

- Hydrogen stands as a prominent secondary energy source, boasting a range of advantages such as its lightweight nature, efficient thermal conductivity, ample reserves, recyclability, high calorific value, superior combustion performance, environmental friendliness, and diverse forms of utilisation. The pivotal divergence between hydrogen energy and traditional fossil energy lies in the fact that hydrogen, serving as an energy carrier, is not procured through natural extraction but rather synthesized via artificial chemical processes. Consequently, the production of hydrogen serves as a foundational component of harnessing hydrogen energy. Presently, hydrogen predominantly originates from fossil fuels and industrial by-products. Hydrogen can be transported in various forms – gas, liquid, and solid – largely dictated by the chosen storage methods.
- As a major secondary energy source, hydrogen energy differs significantly from traditional fossil fuels in that its energy carrier, hydrogen gas, is not naturally obtained but rather synthesized through human-made chemical processes. Thus, the production of hydrogen gas is a fundamental step in utilizing hydrogen energy. Currently, various feedstocks can be used for hydrogen production. Depending on the feedstock, hydrogen production methods can be categorized as non-renewable and renewable. Non-renewable hydrogen production involves using petrochemical fuels and industrial by-products, while renewable hydrogen production primarily utilizes resources like water. Based on the method of hydrogen production and its corresponding carbon emissions, hydrogen can be classified into three categories: gray hydrogen, blue hydrogen, and green hydrogen.



Overview of the Hydrogen Industry in China

Definition of Hydrogen Gas and Analysis of Hydrogen Production Methods (2/2)

Hydrogen Production Technology Route	Definition and Introduction	Characteristic Analysis
<p>Grey Hydrogen</p>	<p>Grey hydrogen refers to hydrogen produced from fossil fuels (e.g., natural gas, coal, etc.) or industrial by-products. Based on the fossil-fuel dominated energy structure in China, in particular coal, grey hydrogen has relatively high availability in China. Due to the advantages of low production cost and mature technology, grey hydrogen is currently the most common hydrogen in China (approximately 97% of total). In 2022, fossil fuel (approximately 78%) was the main source to produce hydrogen, followed by industrial by-products (approximately 19%). The production of grey hydrogen produces some carbon emissions because it involves the combustion of fossil fuels.</p>	<p>Low production costs, relatively simple hydrogen technology, and minimal equipment and space requirements are its advantages. However, it involves greenhouse gas emissions and its construction site is limited by raw material supply.</p> <p>China has abundant coal resources and significant industrial by-products, which is why gray hydrogen production is predominant currently.</p>
<p>Blue Hydrogen</p>	<p>Blue hydrogen refers to hydrogen produced from fossil fuels in combination with CCUS (Carbon Capture, Utilisation and Storage) technology. CCUS technology can achieve low or zero carbon emission in the overall hydrogen production process, but it still relies on fossil fuels as raw materials. Meanwhile, the current cost of CCUS technology is relatively high, so it has not yet been applied on a large scale.</p>	<p>Compared to gray hydrogen, blue hydrogen has relatively lower carbon emissions, but carbon emissions still exist. Its production cost is relatively higher, and it has not yet achieved commercialization.</p>
<p>Green Hydrogen</p>	<p>Green hydrogen refers to hydrogen mainly produced from renewable energy sources (e.g., solar, wind, etc.) through electrolysis of water, with no carbon emission. At present, the production of green hydrogen is generally more costly than that of grey and blue hydrogen, which limits the large-scale application of green hydrogen. Currently, most of the green hydrogen in China is produced in areas with abundant renewable energy resources, such as Inner Mongolia, Hebei Province, etc.</p>	<p>The ideal technological pathway is pure green hydrogen, with zero carbon emissions. However, due to current technological and manufacturing cost constraints, the large-scale implementation of green hydrogen will require time.</p>

Overview of the Hydrogen Industry in China

Overview of Hydrogen Storage Technology Routes

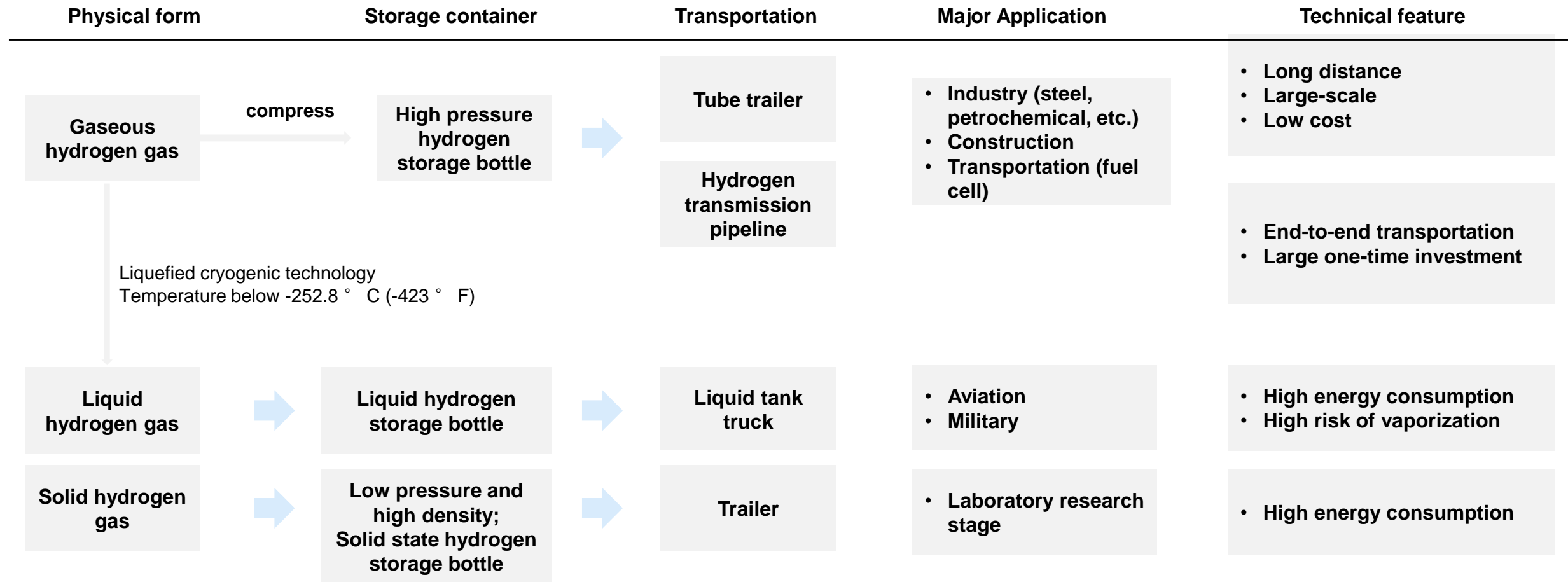
- Presently, hydrogen storage primarily encompasses gaseous hydrogen storage, liquid hydrogen storage, and solid hydrogen storage. Gaseous hydrogen is stored through high-pressure compression – a leading storage method offering rapid charging and discharging, a straightforward container structure, and cost-effectiveness. Furthermore, hydrogen can be stored in a liquid state, boasting high hydrogen storage density. This liquid hydrogen storage can be categorized into low-temperature liquid hydrogen storage and organic liquid hydrogen storage. However, both of these methods are not widely utilized in China. Solid hydrogen storage relies on hydrogen storage carriers like metal hydrides, chemical oxides, or nanomaterials. This is achieved through chemical and physical adsorption, offering advantages like high hydrogen storage density, low storage pressure, safety, and pure hydrogen discharging. Although solid hydrogen storage is still in its nascent research stage, domestic applications have demonstrated its feasibility in distributed power generation. As hydrogen storage technology continues to advance, the future is poised for the increased application of multi-phase hydrogen storage and high-pressure hydrogen storage. These innovations will contribute to the diversification and efficiency of hydrogen storage solutions.

Storage method	Core technology	Advantages	Disadvantages	technology maturity
Gaseous storage	<ul style="list-style-type: none"> High-pressure compression 	<ul style="list-style-type: none"> Low cost Room temperature operation Low hydrogen storage energy consumption Rapid hydrogen charging and discharging 	<ul style="list-style-type: none"> Low hydrogen storage density Large storage container volume Risks of hydrogen leakage and container rupture 	<ul style="list-style-type: none"> The technology is mature and is currently the most commonly used technique.
Cryogenic liquid storage	<ul style="list-style-type: none"> Cryogenic insulation 	<ul style="list-style-type: none"> High energy density High volume density Short refueling time 	<ul style="list-style-type: none"> High costs Significant refrigeration energy consumption High insulation requirements 	<ul style="list-style-type: none"> The technology is mature and primarily applied in the aviation field.
Organic liquid storage	<ul style="list-style-type: none"> Organic hydrogen storage media 	<ul style="list-style-type: none"> High hydrogen storage density High stability Good safety Convenient transportation Reusable hydrogen storage medium Good safety 	<ul style="list-style-type: none"> High costs High dehydrogenation temperatures Significant energy consumption Potential for impurities in hydrogen gas resulting in lower purity 	<ul style="list-style-type: none"> No significant technological barriers remain.
Solid-state storage	<ul style="list-style-type: none"> Physical adsorption Chemical adsorption 	<ul style="list-style-type: none"> High hydrogen storage density High hydrogen purity allowing for purification Convenient transportation, Rapid hydrogen charging and discharging 	<ul style="list-style-type: none"> High cost Constraints in hydrogen storage and release Challenges in heat exchange 	<ul style="list-style-type: none"> The technology is still in the stage of technological improvement and has been demonstrated in applications such as distributed power generation, wind-to-hydrogen, and large-scale hydrogen storage.

Overview of the Hydrogen Industry in China

Overview of Hydrogen Transportation Technology Routes

Hydrogen can be transported in various forms – gas, liquid, and solid – largely dictated by the chosen storage methods. Gaseous hydrogen transportation, notably through long-tube trailers and pipelines, is a predominant long-distance distribution method. Pipeline transportation enables large-scale and extended hydrogen distribution, offering the advantages of substantial transmission capacity, minimized energy consumption, and cost efficiency. However, the construction of pipelines requires significant initial investment. Liquid hydrogen transportation involves storing hydrogen within insulated tanks and subsequently transporting it using liquid hydrogen tanker trucks. Employing liquid hydrogen storage and transportation can reduce vehicle transportation frequency and enhance the supply capacity of individual hydrogen refueling stations. Nevertheless, a primary concern with liquid hydrogen transmission is the potential for evaporation. Solid hydrogen necessitates storage within low-pressure, high-density solid hydrogen storage tanks made of lightweight materials, such as magnesium-based hydrogen storage materials. These technologies are mainly at the pilot study stage. Presently, China primarily employs the 35MPa gaseous high-pressure hydrogen storage and transportation method via long-tube trailers. Looking ahead, as downstream demand for high-pressure hydrogen grows and hydrogen storage and transportation technology matures, storage and transportation technology exceeding 70MPa, alongside low-temperature liquid hydrogen storage, may emerge as mainstream methods.



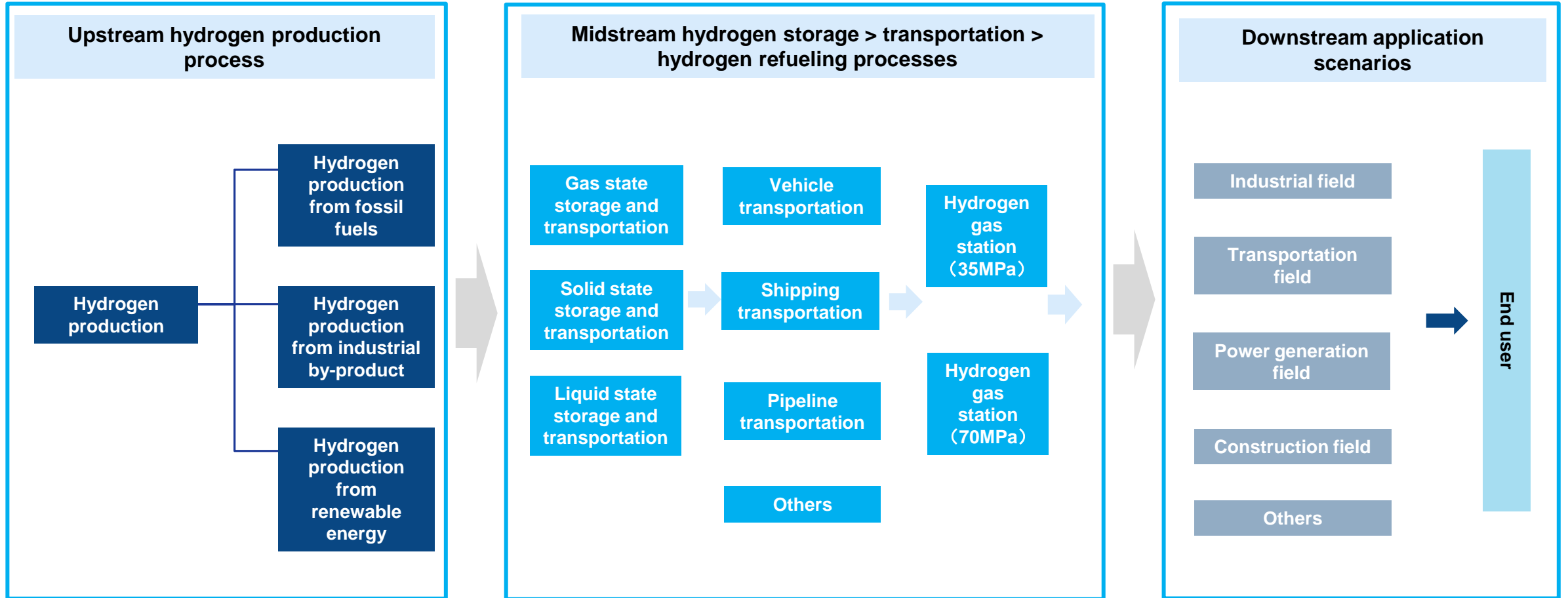
Overview of the Hydrogen Industry in China

Value Chain Analysis

- According to the common usage process of hydrogen energy products, the hydrogen energy industry can be divided into upstream hydrogen production, midstream hydrogen storage, transportation, and refueling, as well as downstream application scenarios. Downstream, based on application scenarios, can be further categorized into industrial field, transportation field, power generation field, construction field, etc.
- Unlike developed Western countries, China's hydrogen energy industry development is characterized by its large scale and a significant proportion of coal-based hydrogen production. Benefiting from China's vast downstream hydrogen consumption market, the hydrogen energy consumption industry in China is more poised to promote the adoption of innovative technologies and commercialization. In recent years, with the increasing investment in research and development by Chinese enterprises in the emerging fields of the hydrogen energy sector, domestic capital markets have also begun to engage in industry layout and commercial products downstream of hydrogen energy consumption, driving the industry into a high-growth phase.
- From a global perspective of hydrogen energy downstream applications, industry is the largest consumption sector, accounting for over 90%. Looking at the long-term consumption structure, guided by hydrogen energy policies, hydrogen is expected to rapidly penetrate the transportation and power generation sectors. Additionally, with the backdrop of technological innovation, infrastructure improvement, and government industry guidance, the global penetration rate of hydrogen energy downstream consumption will continue to grow steadily, expanding market space.
- Similar to the global market, downstream consumption scenarios in China's hydrogen energy product market are dominated by industrial field, transportation field, power generation field, construction field, etc. Benefiting from China's continuous industrial development, hydrogen energy products serve as crucial industrial raw materials with stable and mature demand markets. In the future, as hydrogen energy solutions mature, the transportation and building heating sectors will create even broader commercial market space. Particularly, interactions between vehicle manufacturers and end-users play a key role in the application development and popularization of hydrogen. Vehicle manufacturers need to continuously improve technology, enhance product quality, and reduce costs to attract more users to purchase hydrogen fuel cell vehicles. User demand and feedback can also drive improvements and innovations by vehicle manufacturers, fostering the growth of the entire industry.

Overview of the Hydrogen Industry in China

Value Chain Analysis



Overview of the Hydrogen Industry in China

Industry Landscape of the Hydrogen Energy Industry in China

• Types of hydrogen

The types of hydrogen available in the market include grey hydrogen, blue hydrogen, and green hydrogen. Grey hydrogen refers to hydrogen produced from fossil fuels (e.g., natural gas, coal, etc.) or industrial by-products. Based on the fossil-fuel dominated energy structure in China, in particular coal, grey hydrogen has relatively high availability in China. Due to the advantages of low production cost and mature technology, grey hydrogen is currently the most common hydrogen in China (approximately 97% of total). In 2022, fossil fuel (approximately 78%) was the main source to produce hydrogen, followed by industrial by-products (approximately 19%). The production of grey hydrogen produces some carbon emissions because it involves the combustion of fossil fuels. Blue hydrogen refers to hydrogen produced from fossil fuels in combination with CCUS (Carbon Capture, Utilisation and Storage) technology. CCUS technology can achieve low or zero carbon emission in the overall hydrogen production process, but it still relies on fossil fuels as raw materials. Meanwhile, the current cost of CCUS technology is relatively high, so it has not yet been applied on a large scale. Green hydrogen refers to hydrogen mainly produced from renewable energy sources (e.g., solar, wind, etc.) through electrolysis of water, with no carbon emission. At present, the production of green hydrogen is generally more costly than that of grey and blue hydrogen, which limits the large-scale application of green hydrogen. Currently, most of the green hydrogen in China is produced in areas with abundant renewable energy resources, such as Inner Mongolia, Hebei Province, etc.

• Hydrogen storage

There are three main types of hydrogen storage methods: gaseous, liquid, and solid. Hydrogen can be stored as gas by high pressure compression, which is the main storage method currently, with the advantages of fast filling and discharging, simple structure of containers and low cost. Liquid hydrogen storage has not yet been widely used in China, and solid hydrogen storage is still in the early stage of research. China has seen pilot application of solid hydrogen storage in distributed power generation. With further development of hydrogen storage techniques, approaches such as multi-phase hydrogen storage and high-pressure hydrogen storage will be increasingly applied in the future.

• Hydrogen transport and distribution

Depending on the different storage methods, hydrogen can be transported in gaseous, liquid and solid forms. The transportation of gaseous hydrogen through long-haul trailers and pipelines for long-distance distribution is currently the main method of hydrogen transportation. Thanks to its advantages of large hydrogen delivery capacity, low energy consumption and low cost, pipeline transportation is ideal for large-scale and long-distance hydrogen transportation, but with huge one-time investment for constructing pipelines. Liquid hydrogen can be transported by liquid hydrogen tanks. Liquid hydrogen storage and transportation can improve hydrogen transport efficiency and the supply capacity of each hydrogen refueling station. In addition, hydrogen can be transported by the liquid media such as ammonia and liquid organic hydrogen carriers (LOHC) that are effective for relatively smaller volume and shorter distance. Solid hydrogen should be stored and transported by low-pressure, high-density solid hydrogen storage tanks made of lightweight hydrogen storage materials (such as magnesium-based materials), but this method is still in the pilot study stage.

Overview of the Hydrogen Industry in China

Industry Landscape of the Hydrogen Energy Industry in China

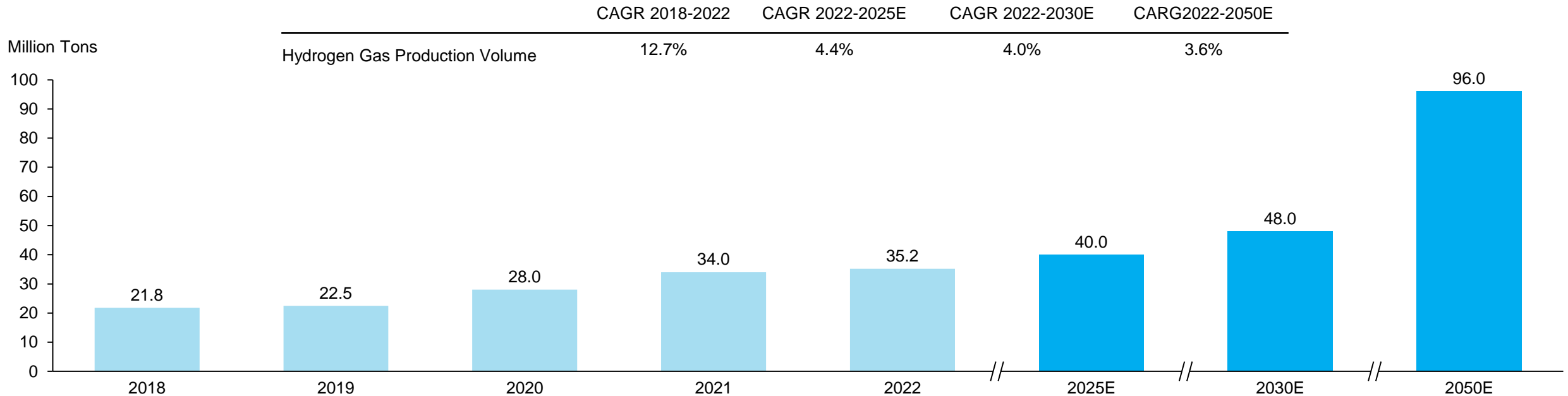
- **Downstream Application of Hydrogen Energy**

Industrial field, transportation field, power generation field and construction field are the major downstream application scenarios of hydrogen energy, of which industrial scenario is currently the dominant application of hydrogen energy. Benefiting from the continued development of China's industry sector, hydrogen energy products, as important industrial raw material, already have a stable and mature demand market. In particular, chemical engineering is the main application scenario of hydrogen energy in the industrial field, including petroleum refining, ammonia synthesis manufacturing, methanol manufacturing, etc. Almost all largescale petroleum refineries in China have on-site hydrogen production equipment. The production of chemical products such as synthetic ammonia and methanol is mainly based on coal chemical industry in China. Most factories use the method of coal gasification to produce hydrogen and then produce different chemical products. Looking forward, the rapid growth of the hydrogen fuel cell industry will drive the application of hydrogen energy in more diverse scenarios such as transportation.

Overview of the Hydrogen Industry in China

Production Volume of Hydrogen Gas in China

Production Volume of Hydrogen Gas (China), 2018-2050E



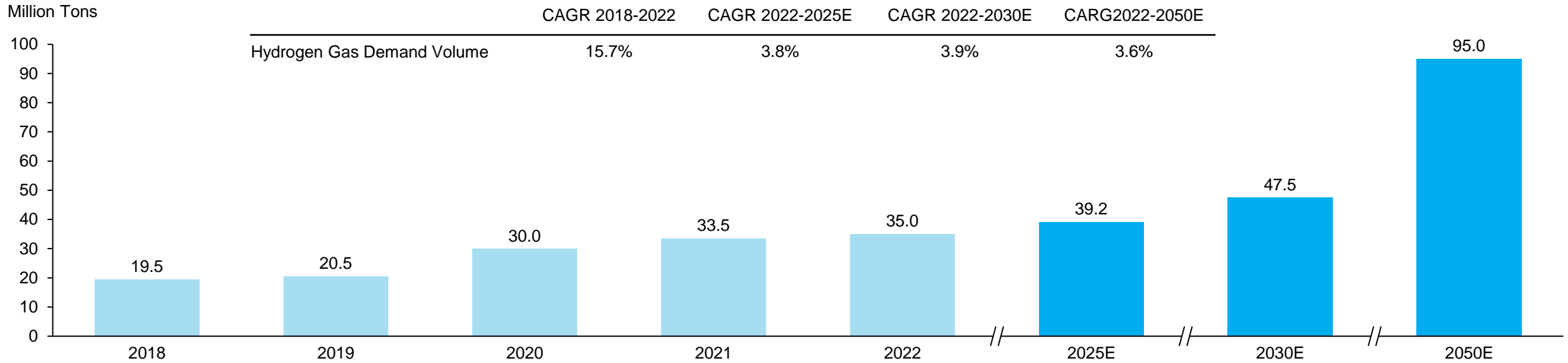
- In recent years, China's hydrogen gas production has exhibited consistent growth. In 2022, the hydrogen gas production volume was approximately 35.2 million tonnes, solidifying China's position as the world's largest hydrogen gas production market. Leveraging its energy profile characterized by "abundant coal, limited oil and gas resources" (“富煤贫油少气”), China predominantly relies on coal and industrial by-products to produce grey hydrogen.

Source: (1) Frost & Sullivan Report, (2) China National Coal Association, (3) China Hydrogen Alliance, and (4) Interviews with industry experts by Frost & Sullivan.

Overview of the Hydrogen Industry in China

Demand Volume of Hydrogen Gas in China

Demand Volume of Hydrogen Gas (China), 2018-2050E



- Between 2018 and 2022, the demand for hydrogen gas in China experienced a gradual uptick, with the industrial sector emerging as a key driver of hydrogen consumption. Notably, hydrogen energy finds widespread application in diverse industries such as petrochemicals, electronics, metal processing, and glass manufacturing. Recognized as a sustainable energy choice, hydrogen energy benefits from government-backed policies aimed at energy transformation and environmental preservation, further fostering its development.
- As a zero-emission transportation solution, hydrogen fuel cell vehicles have garnered considerable attention from the Chinese government. The authorities have introduced a series of supportive measures to encourage the research, development, production, and adoption of hydrogen energy vehicles. With the ongoing enhancement of hydrogen refuelling infrastructure and the continuous introduction of hydrogen fuel cell vehicle offerings by major manufacturers, the transportation sector's demand for hydrogen gas is poised for growth in China. By 2050, the projected hydrogen gas demand is anticipated to reach around 95.0 million tonnes, reflecting a CAGR of approximately 3.6% from 2022 to 2050.

Source: (1) Frost & Sullivan Report, (2) China National Coal Association, (3) China Hydrogen Alliance, and (4) Interviews with industry experts by Frost & Sullivan.

Overview of the Hydrogen Industry in China

Drivers and Trends of the Hydrogen Energy Industry in China and Henan(1/2)

Favourable policies to support the development of hydrogen energy industry

To regulate and bolster the hydrogen fuel cell vehicle sector, the Chinese government has introduced a range of incentive policies in recent years. The “Notice on the Demonstrated Application of Fuel Cell Vehicles,” (《關於開展燃料電池汽車示範應用的通知》) issued in September 2020, outlined guidelines for hydrogen fuel cell vehicle demonstration clusters. This policy rewarded eligible clusters for researching and demonstrating core technology, fostering a strategic model for hydrogen fuel cell vehicle development. Beijing-Tianjin-Hebei city cluster, Shanghai city cluster, Guangdong city cluster, Hebei city cluster, and Henan city cluster were approved as pilot demonstration city clusters since August 2021, each releasing their own implementation rules. The “Opinions of the Central Committee of the Communist Party of China and the State Council on Fully and Accurately Implementing the New Development Concept and Effectively Achieving Carbon Peaking and Carbon Neutrality”, (《中共中央、國務院關於全面準確貫徹新發展理念切實實現碳達峰碳中和的意見》) issued in October 2021, called for the coordinated advancement of the complete hydrogen energy chain encompassing “production, transportation and storage”. The document underscored the necessity of advancing the construction of hydrogen gas stations and large-scale implementation pertaining to hydrogen energy production, storage, and utilization. In March 2022, the “Mid-to-long-term Plan for the Development of Hydrogen Energy Industry (2021-2035)” (《氫能產業發展中長期規劃(2021-2035年)》) provided a “1 + N” policy framework, clarifying strategic hydrogen energy positioning and key developmental tasks.

Henan Government also attached great importance on the development of the hydrogen energy industry. The Henan city cluster is one of such five demonstration city clusters with Zhengzhou city as the leading city. According to the “Implementation Plan for Fuel Cell Demonstration Application in Zhengzhou City Cluster” (《鄭州城市群燃料電池示範應用實施方案》) and relevant requirements of the provincial government, during the four-year demonstration period, the Henan city cluster shall promote 4,445 fuel cell vehicles and construct 82 hydrogen gas stations, forming a complete industrial value chain. In April 2023, the “14th Five-Year Plan for the Development of New Energy and Renewable Energy in Henan Province” (《河南省新能源和可再生能源發展「十四五」規劃》) emphasized scientific hydrogen energy planning, competitive industry chain advantages, broadened application scenarios, and technological innovation. Such favorable policies propel China’s hydrogen energy industry construction and commercial growth.

Cost advantage of hydrogen production industry in China

China stands as one of the largest hydrogen producers in the world, wielding a cost advantage in hydrogen production derived from industrial by-products. Industrial by-products encompass the extraction of hydrogen from residuals generated during other industrial processes. Various sectors in China, including oil refining, chemicals, steel, and coal, yield substantial quantities of such by-products. Employing hydrogen sourced from industrial by-products presents a cost-effective alternative, circumventing the need to construct dedicated hydrogen production facilities. Chinese hydrogen production entities can harness these hydrogen resources from by-products for the extraction, purification, and compression of hydrogen. This approach serves to reduce production costs and enhance overall economic efficiency. In addition, at the same time, the process of extracting hydrogen from industrial by-products is relatively environmentally friendly as this process does not introduce other carbon sources except energy power, which does not generate significant carbon emissions. In addition, the Chinese government actively encourages the development of hydrogen produced from industrial by-products. The “Mid-to-long-term Plan for the Development of Hydrogen Energy Industry (2021-2035)” (《氫能產業發展中長期規劃(2021-2035年)》) released in 2022 proposed to 1) establish a hydrogen energy supply system based on the nearby utilization of industrial by-product hydrogen and renewable energy hydrogen production by 2025; and 2) encourage areas with coking industry clusters to give priority to utilizing hydrogen produced from industrial by-products.

Overview of the Hydrogen Industry in China

Drivers and Trends of the Hydrogen Energy Industry in China and Henan(2/2)

Continuous progress of commercialization of hydrogen energy

Hydrogen energy industry grows rapidly, the scalability of hydrogen production facilities becomes prominent. Innovations in production technology, such as advanced water electrolysis, optimised steam reforming, and catalyst development, further enhances the environmental value of hydrogen energy. With the expansion of the hydrogen fuel cell vehicle market, hydrogen-related infrastructure will also continue to improve, especially hydrogen gas stations, which will continuously evolve to enhance efficiency, reduce refuelling time, and offer user convenience. The integration of evolving production technology, coordinated industry chain advancements, and improved infrastructure accelerates hydrogen energy's commercial progress. This enhanced infrastructure opens avenues for commercial applications, fostering sustainable growth in the hydrogen energy sector.

Continuing advances in hydrogen production, transportation and storage technologies

The ongoing evolution of the hydrogen economy is further propelled by continuing advancements in hydrogen production, transportation, and storage technologies. Grey hydrogen from traditional fossil fuels currently maintains its dominance, but a shift is taking place. Blue hydrogen, utilising CCUS technology, is emerging as a spotlight contender. Nonetheless, the promising path lies in green hydrogen, sourced from water electrolysis powered by renewables. This green variant benefits from both maturing technology and decreasing renewable costs. Looking ahead, the trajectory for low-carbon hydrogen is promising, with an expanding market presence. In the field of storage and transportation, with the further development of hydrogen storage technology, approaches such as multi-phase hydrogen storage and high-pressure hydrogen storage will be increasingly applied in the future. At present, China generally transports 35MPa high-pressure gaseous hydrogen by tube trailers. In the future, with the continuous growth of downstream demand for high-pressure hydrogen and the continuous advancement of hydrogen storage and transportation technology, gaseous storage and transportation technology above 70Mpa level as well as low-temperature liquid hydrogen storage may become the main mode of storage and transportation, and accelerate the penetration of hydrogen energy.

Overview of the Hydrogen Industry in China

Entry Barrier Analysis

Technology barrier

- The technology barriers within the hydrogen energy industry encompass various domains, spanning hydrogen production, storage, transportation, refuelling, application technology, and infrastructure construction. For instance, hydrogen's characteristics, such as its low density and high explosive nature, necessitate overcoming challenges in storage and transportation. Moreover, transmitting hydrogen through pipelines entails considerations like material selection and safety precautions, adding complexity to the equation. Consequently, the development of safer and more efficient hydrogen storage and transportation technologies poses a substantial barrier. Additionally, the versatile nature of hydrogen energy's applications across different fields demands constant technological innovation and adaptive development tailored to each specific domain. As a result, there exist technological barriers to enhancing the maturity and economic efficiency of hydrogen energy utilisation. For new entrants into the industry, challenges related to technology and experience may arise.

Capital barrier

- The hydrogen energy industry requires continuous technology R&D and innovation to improve key technologies such as production, storage, transportation and utilisation of hydrogen. These R&D activities require financial support, including setting up laboratories, hiring R&D personnel, purchasing equipment and materials, etc. In addition, the hydrogen energy industry requires the construction of sound infrastructure facilities, including hydrogen production equipment, storage and transmission equipment, hydrogen gas stations, etc. The construction of these infrastructure requires significant capital investment. In particular, the construction cost of hydrogen gas stations is relatively high, which involves the cost of land acquisition, equipment installation, safety supporting measures, etc. Large-scale production and commercialisation are subject to market risks and operational risks. New entrants do not have sufficient capital reserves, creating a capital barrier.

Production barrier

- Hydrogen production requires a high level of technology and equipment, and different production methods require professional technology and equipment to achieve efficient and sustainable hydrogen production. These technologies and equipment may require significant investment and expertise in engineering. Besides, the production of hydrogen requires a corresponding supply of raw materials and it is a challenge to ensure the stability and sustainability of the supply of raw materials, especially in the face of competition or fluctuations in supply and demand. Some leading enterprises in the industry have the advantage of production cost by deploying the overall industrial chain and making use of their own industrial by-products to produce hydrogen. At the same time, through the close physical layout of the complete industrial chain, it forms a closed-loop business, which has the advantages of economies of scale and resource optimisation, and can effectively reduce production costs and improve competitive advantages.

Customer barrier

- Leading hydrogen energy enterprises in the industry have established stable relationship and cooperation with customers in related industries such as large energy users and main manufacturers, and have good reputation and rich project experience. In addition, demand for hydrogen may vary between industries and customers. New entrants need to understand and meet the needs of different customers and provide customised solutions. This may require more resources and efforts, including technical adaptation, product customisation and marketing. At the same time, downstream customers have higher requirements for the stability and reliability of the supply of hydrogen energy and related products. The new entrants need to establish an efficient supply chain system to ensure timely supply and reliable quality of hydrogen to meet customer needs.

Overview of the Hydrogen Industry in China

Challenges Analysis

Technological and R&D Challenges

The hydrogen energy industry requires continuous technological research and innovation to improve key aspects such as hydrogen production, storage, transportation, and utilization. Currently, challenges persist in areas like high-temperature and high-pressure electrolysis, hydrogen storage, and hydrogen refueling facilities. China needs to increase research and development investments, nurture technical talents, and drive breakthroughs and innovations in critical technologies.

Infrastructure Development Challenges

The hydrogen energy industry requires the establishment of comprehensive infrastructure, including hydrogen production equipment, storage and transportation facilities, and refueling stations. However, the current hydrogen infrastructure in China remains inadequate, necessitating substantial investment and technological support. China needs to enhance efforts in infrastructure development to improve the safety and efficiency of facilities.

Energy Supply and Transition Challenges

The hydrogen energy industry places significant demands on energy supply. Currently, China's primary method of hydrogen production involves reforming fossil fuels, which raises concerns about carbon dioxide emissions. China needs to accelerate its energy transition and promote the utilization of renewable energy sources, such as solar and wind energy, to achieve clean hydrogen production.

Economic Viability and Cost Challenges

Currently, the hydrogen energy industry faces relatively high costs, creating a gap when compared to traditional energy sources. China needs to employ measures such as technological innovation, economies of scale, and resource optimization to reduce the production costs of hydrogen energy, enhancing its economic viability and competitiveness. Addressing these challenges requires collective efforts from the government, businesses, and research institutions. The government should provide increased funding support, policy guidance, and regulatory frameworks to incentivize companies to invest in hydrogen energy research and innovation. Businesses should intensify research and development investments, foster collaboration and partnerships, and enhance the quality and competitiveness of their products and services. Research institutions should enhance their R&D efforts and talent cultivation, providing technical support and solutions.

Overview of the Hydrogen Industry in China

Analysis of Hydrogen Price and Hydrogen Refueling Stations' Cost

- The cost of hydrogen production in China is affected by factors such as raw material cost, energy cost, production equipment cost, transportation cost and carbon emission management cost. In 2022, according to different technology routes, the cost of hydrogen production is low for grey hydrogen, at RMB9-15/kg.
- In terms of the price of hydrogen, since hydrogen in China is currently mainly grey hydrogen produced from industrial by-products, its price is affected by the price of fossil fuels such as coal. From 2018 to 2020, the ex-factory price of hydrogen in Henan Province was relatively stable, maintaining a level of around RMB13/kg. From 2021 to 2022, affected by the rise in coal prices, the ex-factory price of hydrogen has increased, reaching a level of about RMB17/kg. The ex-factory price of high-purity hydrogen is mainly affected by the demand in downstream markets such as hydrogen fuel cells. As the development of the hydrogen fuel cell vehicle market gradually takes off, the demand for high-purity hydrogen is gradually rising. In 2022, the ex-factory price of high-purity hydrogen in Henan Province was approximately RMB23/kg.
- Hydrogen gas station is an important infrastructure to ensure the operation of fuel cell vehicles. As the terminal of the entire hydrogen supply chain, its cost is also included in the cost of hydrogen used. The cost structure of hydrogen gas stations varies depending on factors such as land costs, equipment costs, operation model and technology.
- In the future, with the industrialisation of the hydrogen energy industry and the advancement of hydrogen production, storage and transportation technology, the average retail price of high-purity of hydrogen gas station in China was RMB40-70/kg (without subsidies) in 2022.

Overview of the Hydrogen Industry in China

Policies and Regulations for the Hydrogen Industry - China

Policies and Regulations	Issuing Date	Issuer	Main Content
Outline of the Strategic Plan for Expanding Domestic Demand (2022-2035) 《扩大内需战略规划纲要（2022-2035年）》	2022.12	the State Council	This outline aims to optimize urban transportation network layout and vigorously promote smart transportation. The shift from purchasing-oriented management to usage-oriented management of automotive consumption will be advanced, promoting electrification, connectivity, and intelligence in the automotive sector. Furthermore, it will enhance the construction of supporting facilities such as charging stations and hydrogen refueling stations.
The 14th Five Year Plan for the Development of Modern Logistics 《“十四五”现代物流发展规划》	2022.12	the State Council	The plan emphasizes the development of charging stations and hydrogen refueling stations for freight vehicles, as well as shore power facilities for inland vessels. It actively promotes the use of clean energy sources such as hydrogen in transportation, storage, and distribution sectors. Furthermore, it aims to accelerate the establishment of clean energy supply and refueling systems, including natural gas and hydrogen, for transportation, contributing to the overall expansion of clean energy utilization.
Guiding Opinions on Deepening the Green Development of Industry in the Yellow River Basin 《关于深入推进黄河流域工业绿色发展的指导意见》	2022.12	Ministry of Industry and Information Technology	The guidance encourages the application of alternative energies such as hydrogen in industries such as steel, cement, and chemicals. Taking into account factors like industrial foundations and market potential, it advocates for the orderly advancement of green hydrogen production in provinces and regions like Shanxi, Inner Mongolia, Henan, Sichuan, Shaanxi, and Ningxia. This initiative aims to accelerate coal reduction through substitution measures.
Action Plan for Carbon Peak before 2030 《2030年前碳达峰行动方案》	2021.10	the State Council	The plan aims to promote electric, hydrogen fuel, and liquefied natural gas (LNG) powered heavy-duty freight vehicles. It involves systematically advancing the construction of charging stations, supporting power grids, refueling (gas) stations, and hydrogen refueling stations to enhance the level of urban public transportation infrastructure.

Overview of the Hydrogen Industry in China

Policies and Regulations for the Hydrogen Industry - China

Policies and Regulations	Issuing Date	Issuer	Main Content
<p>Notice on the Application Guidelines for 2021 Targeted Projects of the National Key R&D Plan "Hydrogen Energy Technology" Key Special Project 《国家重点研发计划“氢能技术”重点专项2021年度定向项目申报指南的通知》</p>	2021.09	Ministry of Science and Technology	<p>In 2021, as part of the comprehensive demonstration technology direction of the “Hydrogen Enters Every Household” (氢进万家) initiative, a targeted project is planned to be initiated, with an allocated budget of 150 million yuan from the national funds. The overall requirements for the application demonstration include: demonstration operation of 3,000 or more fuel cell vehicles, operation of 15 or more hydrogen refueling stations, cumulative vehicle operation mileage of no less than 100 million kilometers, hydrogen usage of no less than 10,000 tons, and hydrogen usage of no less than 10,000 tons for fuel cell co-generation.</p>
<p>Notice on Conducting Demonstration Applications of Fuel Cell Vehicles 《关于开展燃料电池汽车示范应用的通知》</p>	2020.09	Ministry of Finance, Ministry of Industry and Information Technology, Ministry of Science and Technology, Development and Reform Commission, National Energy Administration	<p>In response to the current situation of industrial development, the five departments provide support policies for the demonstration application of fuel cell vehicles, and reward eligible urban agglomerations for carrying out industrialization research and demonstration application of key core technologies of fuel cell vehicles, forming a new model of fuel cell vehicle development with reasonable layout, different focuses, and coordinated promotion. The demonstration period is tentatively set at four years. Demonstration city clusters should focus on technological innovation, identify application scenarios, and build a complete industrial chain. One is to build a fuel cell vehicle industry chain and promote the research and development and industrialization of various links in the chain. The second is to carry out demonstration applications of new technologies and new models of fuel cell vehicles, and promote the establishment and improvement of relevant technical indicator systems and testing and evaluation standards. The third is to explore effective business operation models and continuously improve economic efficiency. The fourth is to improve the policy and institutional environment. We need to establish a comprehensive support policy system for the research and development of core technologies for hydrogen and fuel cells, the construction and operation of hydrogen refueling stations, and the demonstration and application of fuel cell vehicles.</p>

Overview of the Hydrogen Industry in China

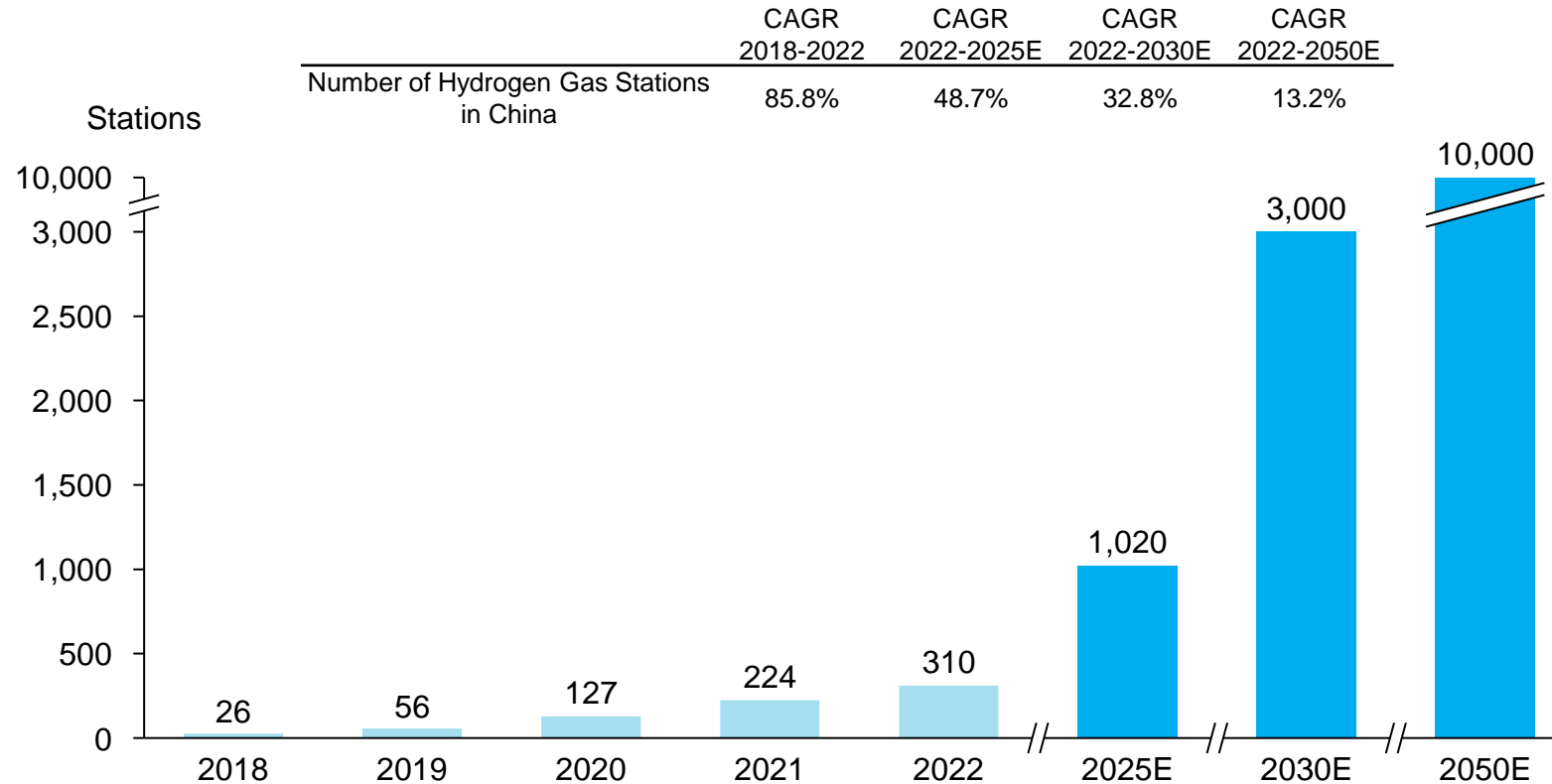
Policies and Regulations for the Hydrogen Industry - Henan

Policies and Regulations	Issuing Date	Issuer	Main Content
<p>Medium and Long-Term Development Plan for Hydrogen Energy Industry in Henan Province (2022-2035)</p> <p>《河南省氢能产业发展中长期规划（2022-2035年）》</p>	2022.09	General Office of Henan Provincial People's Government	<p>The plan is based on hydrogen energy's three main positions: as an efficient and low-carbon terminal energy source, an intelligent and flexible energy storage carrier, and a green and clean industrial raw material. It adheres to the path of "innovation-driven, industrial enhancement, safety first, and demonstration-led." It relies on key backbone enterprises and implements the innovation-driven development strategy comprehensively. This involves intensifying research and development efforts in core technological equipment, fostering and elevating industrial competitive advantages. Emphasis is placed on effective fuel cell vehicle demonstrations, strategically advancing infrastructure deployment, actively exploring application scenarios, progressively refining institutional mechanisms, and driving deep integration across industrial chains, innovation chains, supply chains, factor chains, and system chains. All of this is aimed at providing new impetus for the province's energy transition and the high-quality development of equipment manufacturing.</p>
<p>The Plan and Construction Work Scheme for Zheng-Bian-Luo-Pu Hydrogen Corridor</p> <p>《郑汴洛濮氢走廊规划建设工作方案》</p>	2022.09	General Office of Henan Provincial People's Government	<p>The "Zheng-Bian-Luo-Pu Hydrogen Corridor"（郑汴洛濮氢走廊）is a key initiative that focuses on establishing a "One Axis, Five Nodes, Three Bases" layout. This corridor encompasses the hydrogen energy application demonstration belt of Zheng-Bian-Luo-Pu, with five major industrial support nodes in Zhengzhou, Kaifeng, Luoyang, Xinxiang, and Puyang. The "Plan" emphasizes the development of significant projects as the core strategy, centered around the construction of the "One Axis, Five Nodes, Three Bases" layout. The goal is to create a prominent, distinctive, fully functional, and province-wide radiating "Zheng-Bian-Luo-Pu Hydrogen Corridor."</p>
<p>Notice on Adjusting the Incentive and Compensation Policies for the Promotion and Application of New Energy Vehicles and Charging Infrastructure in Henan Province</p> <p>《关于调整河南省新能源汽车推广应用及充电基础设施奖补政策的通知》</p>	2018.06	Henan Provincial Department of Finance	<p>The "Notice" proposes providing a promotion and application subsidy of 30% of the national subsidy standard for new energy special-purpose vehicles, trucks, and fuel cell vehicles. This subsidy will be adjusted in accordance with the further refinement of national standards.</p>
<p>Notice on Jiyuan's 14th Five Year Plan for Technological Innovation and Development</p> <p>《济源“十四五”科技创新发展规划的通知》</p>	2022.10	Jiyuan Municipal People's Government	<p>Key technological focuses for traditional advantageous industries include the development and production technology of coal chemical catalysts such as platinum, ruthenium, and rhodium-based catalysts, as well as the technology for producing green methanol (liquid combustible hydrogen). Emphasis is placed on significant technological demands in future industries such as hydrogen energy and energy storage, cutting-edge new materials, future networks, quantum information, etc. Guided by the principles of "transforming existing industries for the future" and "commercializing future technologies," efforts will be intensified in fundamental research to achieve technological breakthroughs. This will establish a technology conversion chain encompassing research and development, industry application, and deployment, in order to support and lead the initial and continuous growth of future industries.</p>

Overview of the Hydrogen Industry in China

Number of Hydrogen Gas Stations in China

Number of Hydrogen Gas Stations (China), 2018-2050E



- The number hydrogen gas stations in China increased from 26 in 2018 to 310 in 2022, demonstrating a remarkable CAGR of 85.8%. With proactive efforts from industry leaders and robust governmental backing, the trajectory indicates that the number of hydrogen gas stations in China is poised to continue its steady expansion. The projection foresees China's hydrogen gas station count surpassing 1,000 by 2025, reaching 3,000 by 2030, and exceeding 10,000 by 2050. This extensive network will provide a robust foundation for new energy vehicle development and will play a pivotal role in driving China's energy transformation and sustainable development.

Source: (1) Frost & Sullivan Report, and (2) Interviews with industry experts by Frost & Sullivan.

Overview of the Hydrogen Industry in China

Competitive Landscape of the High-purity Hydrogen Gas Industry in Henan Province

- At present, due to technological and production constraints in obtaining high-purity hydrogen gas, as well as the early stage of development for hydrogen fuel cell vehicles and hydrogen gas stations in Henan province, the supply of high-purity hydrogen gas in the region was approximately 10,700 tonnes in 2022. In the same year, there were 5-10 major suppliers of high-purity hydrogen gas in Henan province. These suppliers are primarily concentrated in the coking industry hub. They choose to produce hydrogen gas from crude coking coal gas, leveraging their regional context and industrial characteristics. This approach allows them to efficiently utilise abundant upstream crude coking coal gas, employing extraction and purification technologies to generate industrial-grade and high-purity hydrogen. Subsequently, they distribute these products to neighbouring chemical enterprises, new energy public transportation systems (hydrogen gas stations), power plants, and other downstream customers through pipelines and tube vehicles. In the coming years, as the hydrogen energy industry in Henan province advances and downstream demand for high-purity hydrogen gas increases, it is anticipated that high-purity hydrogen gas suppliers in Henan province will enhance their purification processes, expand production capacities, and forge closer collaborations with downstream customers. These collective efforts will drive the evolution of hydrogen energy infrastructure in Henan province and foster the practical application of hydrogen energy within diverse transportation sectors.

Agenda

- 1 Overview of Macro Economic Environment
- 2 Overview of Refined Chemicals Derived from Coal Chemical Coking Industry in China
- 3 Overview of the LNG Industry in China
- 4 Overview of the Coal Gas Industry in China
- 5 Overview of the Hydrogen Energy Industry in China
- 6 **Appendix**



Overview of Synthetic Ammonia Market in China

Supporting Statements

It is an industry norm for a supplier of benzene-based chemicals and energy products to produce on its own and procure from third-party suppliers the same type of products, taking into account, among others, its own production capacity, the cost of production and the production lead time.

As of 3 December 2023, the Company was the only enterprise which entered into such cooperation agreement in respect of hydrogen refuelling stations with the Committee in Zhengzhou High-Tech Industrial Development Zone, being one of the pilot regions for the development of hydrogen business in Zhengzhou.

(i) the conversion of m³ into tonne for LNG have been made at the ratio of 1,390 m³ to 1 tonne and vice versa; (ii) the conversion of tonne into kg for LNG have been made at the ratio of 1 tonne to 1,000 kg and vice versa; (iii) the conversion of m³ into tonne for hydrogen have been made at the ratio of 11,123.5 m³ to 1 tonne and vice versa; and (iv) the conversion of m³ into kg for hydrogen have been made at the ratio of 1 m³ to 0.0899 kg and vice versa.

There is a gap in the local supply based on the difference between production and consumption in Henan province. A good symbiosis with large-scale coke producers has been developed in Jiyuan city, the downstream chemical companies have also established business operations within the vicinity to form a cluster effect for the consideration of transportation cost.

China Pingmei Shenma Group Co., Ltd. is a state-owned mega-size enterprise group with energy and chemical industries as its main business. It is one of the top 50 coal enterprises according to the 2022 China Top 50 Coal Enterprise list released by the China Coal Industry Association, and ranks ninth in the PRC and first in Henan province in terms of revenue.

It is an industry norm for LNG suppliers to mainly sell LNG to trading customers.

Hydrogenated benzene-based chemicals suppliers that purchase hydrogenated benzene-based chemicals from hydrogenated benzene-based chemicals manufacturers usually ask for a higher selling price than manufacturers as they need to cover their additional costs incurred in the trading process and to maintain profit margin while having limited control over the quality of products.

It is an industry norm for a market player of benzene-based chemicals and energy industries to have sales and purchases with other players, taking into account, among others, its own production capacity, the cost of production and the production lead time.

Competition in the benzene-based chemicals and energy industries in Henan Province is based on many factors, such as price and cost, production capacity, transport capabilities and quality.

Overview of Synthetic Ammonia Market in China

Supporting Statements

In relation to LNG production, the growth in demand for natural gas is driven by the Energy Production and Consumption Revolution Strategy (2016-2030) (《能源生產和消費革命戰略(2016-2030)》), which provides that natural gas in China will become one of the important components of energy structure transformation by 2030 accounting for 15% of China's energy consumption. In light of the substantial energy consumption in Henan province and the low domestic natural gas supply capacity, a notification titled "Notice of the People's Government of Henan province on Issuing the 14th Five Year Plan for Modern Energy System, Carbon Peak, and Carbon Neutrality of Henan Province" (《河南省人民政府關於印發河南省「十四五」現代能源體系和碳達峰碳中和規劃的通知》) was released in 2021. The notice introduced the idea of replacing high carbon fossil fuels with low carbon alternatives such as natural gas and placed an emphasis on expediting the establishment of a comprehensive production supply storage sales system for clean energy, specifically natural gas, with the aim of enhancing overall energy supply stability and security. These policies promote a transition from coal usage to the utilisation of natural gases, which has positively impacted our clean energy business.

Furthermore, policies such as the "Outline of the 14th Five-Year Development Plan for the Coking Industry" (《焦化行業「十四五」發展規劃綱要》), has significantly bolstered the expansion of our coal-based coking gas business. The policy highlighted the importance of promoting circular economy benefits within coking parks and agglomeration zones to create a conducive environment for the advancement of coal-based coking natural gas. It also promoted "zero emissions" in coking parks. Thereby supporting the sustainable development of the coal-based coking natural gas industry.

Our hydrogen production business also benefited from a series of favourable governmental policies to support the development of hydrogen energy. In September 2020, the issue of the "Notice on the Demonstrated Application of Fuel Cell Vehicles" (《關於開展燃料電池汽車示範應用的通知》) rewarded eligible city clusters to carry out research and demonstrated application of hydrogen fuel cell vehicles. Henan province was approved as one of the city clusters in August 2021. The "Action Plan for Carbon Peak before 2030" (《2030年前碳達峰行動方案》) issued in October 2021 and the "14th Five Year Plan for the Development of Modern Logistics" (《“十四五”現代物流發展規劃》) in December 2022 promoted the construction and development of hydrogen gas stations amongst other clean energy sources. Further, in April 2023, the Henan Development and Reform Commission issued the "14th Five-Year Plan for the Development of New Energy and Renewable Energy in Henan Province" (《河南省新能源和可再生能源發展「十四五」規劃》), which emphasized on the promotion of technological innovation in the field of hydrogen energy.

The development of our hydrogenated benzene-based chemicals business was bolstered by policies such as the "Implementation Guidelines on Renovation and Upgrading of Energy Saving and Carbon Reduction for Modern Coal Chemical Industry" (《現代煤化工行業節能降碳改造升級實施指南》) and the "Action Plan for Industrial Energy Efficiency Improvement" (《工業能效提升行動計劃》). The policies promoted the adoption of environmentally friendly technology and practices within the coal chemical industry through the implementation of energy-saving equipment in the production process of modern coal chemical industry and hydrogenated benzene-based chemicals. By improving the sustainability and efficiency of the coal chemical industry, these policies support the continual growth of our hydrogenated benzene-based chemical business.

The PRC Government is committed to encourage the development of circular economy and "dual carbon goals (雙碳目標)" and the green and low-carbon transformation.

Jinma Group is a leading coking coal producer in Henan Province and has large coking coal production scale.

Situated at the junction of Shanxi and Henan provinces which enjoys prominent location advantage, the Company are adjacent to the national railway network, major highways and expressways in North China. Meanwhile, extreme weather and highway traffic restrictions during holidays could result in a reduced inflow of resources from within and outside the province.

Overview of Synthetic Ammonia Market in China

Supporting Statements

Hydrogenated benzene-based chemicals are basic chemical raw materials and an essential part of the chemical industry chain.

Situated at the junction of Shanxi and Henan provinces helps to ensure the supply of crude benzene as raw materials and the sale of pure benzene by relying on the abundant coking resources in the two provinces.

LNG is an odourless, colourless, non-corrosive and non-toxic natural gas which can be converted into liquid by compressing and cooling it to -161.5° C. It comprises mostly of methane and a small percentage of ethane, oxygen and nitrogen.

Pure benzene is a colourless, toxic and highly flammable liquid. It is primarily used as an industrial solvent, a precursor for manufacturing nylon, dyes, plastics, drugs, explosives and synthetic rubber.

Toluene is a colourless, water-insoluble liquid. It is primarily used in manufacturing sweeteners, drugs and dyes, and can also be used as a solvent.

Xylene a colourless, flammable and water-insoluble liquid. It is primarily used in pesticides, paint thinner, paints and varnishes and can be used as solvent.

Hydrogen is among the cleanest fuels for powering vehicles. This is made possible thanks to the development in fuel cell technology that can be applied in electric vehicles using compressed hydrogen. Hydrogen can be produced from chemical processing of coal or from electrolysed water derived from renewable energy such as solar energy (by using solar panels) and wind energy (by using wind turbines).

Global efforts have been made to combat climate change through the “United Nations Framework Convention on Climate Change” which was enhanced by the “Paris Agreement”. The PRC Government has strong commitments to its “dual carbon goals (雙碳目標)”, namely to reach peak carbon emission by 2030 and to achieve carbon neutrality by 2060.

In 2021, the PRC Government launched the first batch of demonstration city clusters and has formulated clear development goals and strategic plans for the fuel cell vehicle industry, and a series of detailed incentive plans to stimulate the development of the industry since then. The Henan city cluster is one of such five demonstration city clusters with Zhengzhou city as the leading city. According to the Implementation Plan for Fuel Cell Demonstration Application in Zhengzhou City Cluster* (《鄭州城市群燃料電池示範應用實施方案》) and relevant requirements of the provincial government, during the four-year demonstration period, the Henan city cluster shall promote 4,445 fuel cell vehicles and construct 82 hydrogen gas stations, forming a complete industrial value chain. In particular, during the four-year demonstration period, Zhengzhou shall promote 2,100 fuel cell vehicles and construct 40 hydrogen gas stations. In addition, there are six types of fuel cell vehicles targeted, namely buses (公交), tractors (牽引車), sanitation vehicles (環衛車), muck trucks (渣土車), light trucks (輕卡車) and cement mixer trucks (水泥攪拌車). Zhengzhou High-Tech Industrial Development Zone (鄭州高新技術產業開發區) is one of the pilot regions for the development of hydrogen business in Zhengzhou.

In addition, among the 11 gas stations with hydrogen refuelling facilities constructed in Zhengzhou city as of 18 August, none of the operators has its own hydrogen supply.

Overview of Synthetic Ammonia Market in China

Supporting Statements

Hydrogenated benzene-based chemicals are basic chemical raw materials and an essential part of the chemical industry chain.

In general, prices of crude benzene changes rapidly.

The coking process yields a wide variety and combinations of coking by-products with carbon being the essential element. Coke manufacturers naturally require uptakers to which their coking by-products could be offloaded. In particular, crude coking coal gas that cannot be sold or utilised would otherwise have to be burned as wastage. The other side of the same coin is that processors of crude coking coal gas need a reliable source from which to source their raw materials. As a result of this symbiotic relationship between coke manufacturers and processors of crude coking coal gas, it can be consistently observed in the coking industry that wherever there is a coke manufacturer of a sufficient scale, it would attract other chemical companies in this symbiotic carbon ecosystem to establish businesses nearby for up-taking the former's crude coking coal gas.

The coking industry is a capital-intensive one, the entry into which requires substantial investments in, for example, land, factory, equipment, coke oven and pipelines. Additionally, large-scale production is usually a pre-requisite for coke producers to effectively compete in the market. Further barriers to entry into the coking industry are the strict regulations and policies laid down in the PRC that are aimed at eliminating coking enterprises with outdated and inefficient equipment and technology as well as enhancing environmental protection measures.

Crude coking coal gas is in practice only transported in its gaseous form owing to its chemical properties, i.e. it condenses only at a very low temperature and very high pressure, and as such, crude coking coal gas is usually delivered through pipelines, the construction of which comes with a myriad of constraints. Firstly, laying out a set of pipelines requires extensive planning, especially where long-distance delivery is concerned, and may often involve difficulties in planning around public land and/or negotiation with owners of private properties through which the pipes are intended to go through. Also, the costs of construction (as well as that of subsequent maintenance) rise exponentially with the distance of delivery (i.e. the length of the pipelines).

There are a limited number of other coking enterprises within Henan province which are comparable in scale to the Jinma Group.

The crude coking coal gas produced by these coking enterprises is mainly for self-use, such as for their own downstream processing of coking by-products as well as for power generation.

Circular economic development (內循環) is a national policy objective in the PRC as promoted by, among others, the "14th Five Year Plan" (for 2021 to 2025), and the Circular Economy Promotion Law (中華人民共和國循環經濟促進法) (the "CEPL"). A circular economy includes different ecosystemic cycles within industries and businesses, and entails (as defined in the CEPL) activities of "reducing, reusing and reutilising (減量化、再利用、資源化)" in the process of production, circulation and consumption. In this regard, our sourcing of crude coking coal gas, being a by-product from the Jinma Group's business, constitutes "reutilising" under the CEPL. Also pertinently, Article 29 of the CEPL stipulates that enterprises in industrial parks should be organised for comprehensive utilisation of resources and promotion of circular economy.

The emphasis of the PRC Government on circular economic development is consistent with current business development trends and existing commercial practices where close physical proximity among enterprises within a supply chain forming an ecosystem is essential for the success of modern-day manufacturing.

There are no other substantial clean energy products business within the Jiyuan High-Tech Industrial Chemical Park that has the appetite for the Jinma Group's crude coking coal gas.

Overview of Synthetic Ammonia Market in China

Supporting Statements

Crude coking coal gas is in practice only transported in its gaseous form owing to its chemical properties, i.e. it condenses only at a very low temperature and very high pressure.

The Company is in a industry that is dominated primarily by male professionals with science background.

The demand for hydrogenated benzene-based chemicals are affected by the development in the nylon and fertilisers manufacturing and chemicals industry.

Due to the inherent difficulty in transporting crude coking coal gas which can only be supplied in close proximity and preferably through pipes, there are no alternative suppliers of crude coking coal gas that are readily available to provide crude coking coal gas to the Company under similar terms as the Jinma Group.

Overview of Synthetic Ammonia Market in China

Supporting Statements

Crude coking coal gas is in practice only transported in its gaseous form owing to its chemical properties, i.e. it condenses only at a very low temperature and very high pressure.

The Company is the largest pure benzene supplier in Henan province with a market share of 18.6%, with the market size of pure benzene in Henan province accounting for approximately 3.4% of the market share in China; and the third largest LNG supplier in Henan province with a market share of 4.9%, with the market size of LNG in Henan province accounting for approximately 1.8% of the market share in China.

Hydrogenated benzene-based chemicals are produced through hydrogenation, namely the adding of hydrogen in the presence of catalyst, of crude benzene.

Luoyang Refinery is one of the fuel-based oil refinery companies with 5 million tonnes per year whose construction was approved by the PRC government during the fifth Five-Year Plan.

The hydrogen produced by Jinjiang Refinery is classified as “grey hydrogen”.

The Group is the most geographically proximal to Pingmei Shenma when compared to other hydrogenated benzene-based chemicals suppliers with comparable scale in Henan province.

There are over 50 companies in the PRC which are engaged in the above businesses with similar scale.

As coke granules are commodities that can be easily sourced from Independent Third Parties, there is an abundant supply in the market with a diversified supplier base.

LNG is a commodity that can be easily sold within the LNG market at the prevailing market price.

The production or processing of hydrogenated benzene-based chemicals and energy products as well as the operation of oil and gas stations and hydrogen gas station are inherently dangerous in nature. For instance, benzene is considered to be carcinogenic. If leakage occurs during the benzene production process, it may cause harm to the health of the production personnel. In addition, hydrogen used in fuel cells is a very flammable gas and can cause fire and explosion if it is not handled properly.

Overview of Synthetic Ammonia Market in China

Supporting Statements

Product	Usage/products
Coke	As a reducing agent, heat agent and column skeleton for the blast furnace production of iron and steel.
Crude benzene	For production of hydrogenated benzene-based chemicals (e.g. pure benzene and toluene).
Coal tar	For production of coal tar-based chemicals (e.g. coal asphalt, coal tar pitch, naphthalene, and anthracene oil).
Crude coking coal gas	Crude coking coal gas contains carbon monoxide, hydrogen and methane which are chemical raw materials.
Coal asphalt	As electrode binders in the metallurgical industry.
Anthracene oil	For production of pigments, wood preservatives, insecticides and coating materials.
Industrial naphthalene	For manufacture of concrete superplasticisers, dyes, plastics and solvents.
LNG	As a clean fuel for vehicles and industrial use.
Hydrogen	For use in refining petroleum and crude benzene, in the production of other base chemicals like methanol, and as a fuel for vehicles with hydrogen fuel cells.
Coal gas	As domestic fuel or industrial fuel, and as a raw material in the production of hydrogen and various chemical products.
Pure benzene	As an industrial solvent and a precursor for the manufacture of nylon, dyes, plastics, drugs, explosives and synthetic rubber.
Toluene	For manufacture of sweeteners, drugs and dyes; toluene can also be used as a solvent.

Research Methodologies

- Frost & Sullivan is an independent global consulting firm, which was founded in 1961 in New York. It offers industry research and market strategies and provides growth consulting and corporate training. Its industry coverage includes automotive and transportation, chemicals, materials and food, commercial aviation, consumer products, energy and power systems, environment and building technologies, healthcare, industrial automation and electronics, industrial and machinery, and technology, media and telecom.
- The Frost & Sullivan's report includes information on benzene-based chemicals and energy industries.
- Frost & Sullivan has conducted detailed primary research which involved discussing the status of the industry with certain leading industry participants and conducting interviews with relevant parties. Frost & Sullivan has also conducted secondary research which involved reviewing company reports, independent research reports and data based on its own research database. Frost & Sullivan has obtained the figures for the estimated total market size from historical data analysis plotted against macroeconomic data as well as considered the above-mentioned industry key drivers.
- Frost & Sullivan's Market Engineering Forecasting Methodology integrates several forecasting techniques with the Market Engineering Measurement-based System. It relies on the expertise of the analyst team in integrating the critical market elements investigated during the research phase of the project. These elements include:
 - ✓ Expert-opinion forecasting methodology
 - ✓ Integration of market drivers and restraints
 - ✓ Integration with the market challenges
 - ✓ Integration of the Market Engineering Measurement trends
 - ✓ Integration of econometric variables
- In compiling and preparing the Report, Frost & Sullivan has adopted the following assumptions:
 - ✓ The social, economic and political environment of the globe and China is likely to remain stable in the forecast period
 - ✓ Related industry key drivers are likely to drive the market in the forecast period

Source: Frost & Sullivan