

Confidential

## Independent Market Research on Global and China Hydrogen Energy Core Equipment Industries

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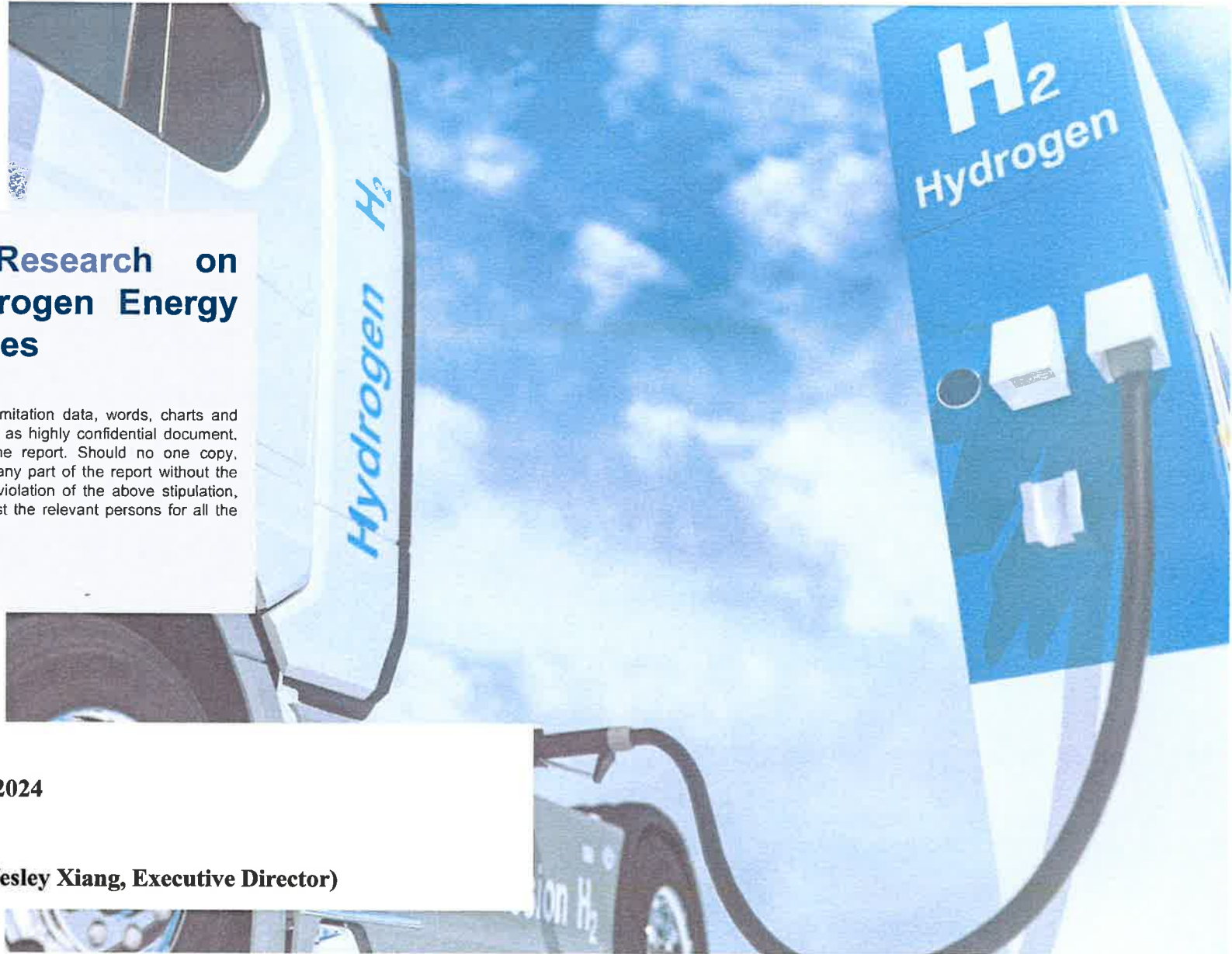
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# Overview of the Hydrogen Energy Industry

## Overview of Global Hydrogen Energy Industry

- Hydrogen is a prominent secondary energy source, which can be produced by conversion of primary energy sources, such as fossil fuel and renewable energy. Hydrogen boasts a number of advantages, including wide availability, low-carbon emission, high flexibility and efficiency and diverse applications. Hydrogen has a high energy density and significantly higher thermal value than fossil fuels. It can be used broadly in various fields, such as industrial, transportation, power generation, energy storage and construction, among others.
- As countries strive to meet ambitious emissions reduction targets and transition towards sustainable energy systems, hydrogen emerges as a key solution driven by its pivotal role in addressing pressing challenges such as climate change, promoting energy structure transformation, and ensuring energy security. The race to develop and scale up hydrogen energy industries in the major countries and regions around the world further underscores its significance in shaping the future of global energy systems and addressing the urgent imperatives of climate action and energy resilience. According to the data published by International Energy Agency (“IEA”) and the International Renewable Energy Agency it is estimated that hydrogen energy will meet 12%-13% of global final energy demand by 2050. By the end of 2023, more than 40 countries and regions around the world have announced hydrogen energy strategies, and the countries that have released national hydrogen energy strategies cover major economies with more than 80% of the world’s GDP. Investment in the global hydrogen energy industry has grown rapidly in the past few years. According to the data published by the Bloomberg New Energy Finance, global investment in hydrogen-related projects reached US\$34 billion in 2023, a year-on-year increase of 146%. In addition, according to the report released by IEA, the spending on electrolyser installations has consistently increased over the past few years and hit a new record in 2022, at US\$0.6 billion globally, double the 2021 value. The following sets forth the overview of the hydrogen energy industries in the representative markets in the world:

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Overview of Global Hydrogen Energy Industry

### Asia

- In Asia, the development of the hydrogen energy industry is also driven by ambitious regional and national policies. China, for instance, unveiled its “Medium and Long-term Development Plan for Hydrogen Industry (2021-2035)” (《氢能產業發展中長期規劃(2021-2035年)》) in March 2022 which regards hydrogen energy as an important strategy for the country’s future development and aims to form a complete hydrogen energy industry system by 2030. Similarly, Japan launched its Basic Hydrogen Strategy in December 2017, aiming to create a hydrogen-based society by 2030 and become a leading global supplier of hydrogen-related technologies and services. In June 2023, the government of Japan issued Hydrogen Basic Strategy, planning to contribute upfront investments worth JPY20 trillion in order to attract the public and private sectors to Green Transformation initiatives-related investments and achieve combined investments of JPY150 trillion or more over the next decade. Korea issued Basic Plan for the Implementation of Hydrogen Economy in November 2021, setting the goal of producing 27.9 million tons of low-carbon hydrogen by 2050. Hydrogen is expected to be the largest source of energy in Korea in 2050 supplying 33% of energy consumption and 24% of electricity generation in Korea. Similarly, in January 2023, India launched the “National Green Hydrogen Mission” with the aim of making it a global hub for green hydrogen manufacturing and exports. This mission aims to achieve a targeted production capacity of 5 million tonnes per annum of green hydrogen by 2030. Asia’s hydrogen energy industry benefits from diverse and complementary strengths across different countries. China boasts significant manufacturing capabilities and a growing renewable energy sector, providing opportunities for large-scale hydrogen production and deployment. Japan, on the other hand, has been at the forefront of fuel cell technology development and is investing in hydrogen infrastructure. Singapore, despite its limited land area, is exploring innovative solutions such as hydrogen imports and partnerships to overcome challenges related to domestic hydrogen production and storage. One prominent trend of the hydrogen energy industry in Asia is the increasing emphasis on international cooperation and partnerships to promote the market development. Countries in the region are also investing in R&D to drive down the costs of hydrogen energy.

Source: Frost & Sullivan

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## Overview of Global Hydrogen Energy Industry

### Middle East

- In the Middle East, particularly in countries like Saudi Arabia, UAE and Egypt, the hydrogen energy industry is gaining significant attention as part of broader strategies to diversify their economies away from traditional hydrocarbon resources. Saudi Arabia announced its National Industrial Development and Logistics Program in 2019, which outlined plans for the development of a hydrogen economy. The program aims to leverage the country's abundant renewable energy resources, particularly solar power, for green hydrogen production. Similarly, the UAE plans to develop its domestic hydrogen production capabilities, fostering innovation, and positioning the UAE as a hub for hydrogen trade and technology development. In January 2020, Mubadala Investment Company (Mubadala), the Abu Dhabi National Oil Company, and Abu Dhabi Development Holding Company established the Abu Dhabi Hydrogen Alliance. The alliance partners will collaborate to position Abu Dhabi as a trusted leader of low-carbon green and blue hydrogen in emerging international markets. In November 2023, the UAE launched its new National Hydrogen Strategy, signaling a strong commitment to becoming a key player in the hydrogen energy industry. The strategy targeted that the hydrogen production capacity in the UAE will reach 1.4 million tons/year by 2031 (consisting of 1.0 million tons per year of green hydrogen and 0.4 million tons per year of blue hydrogen), 7.5 million tons per year by 2040, and 15.0 million tons per year by 2050. In 2022, Egypt announced that it would formulate a hydrogen energy strategy with the European Bank for Reconstruction and Development and would invest US\$40 billion in the construction of green hydrogen-related facilities. In January 2024, the Egyptian parliament passed legislation enabling a green hydrogen subsidy scheme which offers a generous tax credit of up to 55%, as well as wider non-tax incentives, to project developers. One of the key characteristics of the hydrogen energy industry in the Middle East is the region's abundant renewable energy resources, particularly solar energy. This provides a significant advantage for green hydrogen production through water electrolysis. Moreover, the Middle East's established infrastructure and experience in the energy sector position it well to scale up hydrogen production and export operations efficiently. Looking ahead, the hydrogen energy industry in the Middle East is expected to experience rapid growth as countries in the region continue to invest in the development of their hydrogen sectors. Key trends include increasing investment in large-scale hydrogen projects, advancements in technology to improve the efficiency of hydrogen production and utilization, and the establishment of international partnerships to drive innovation and market expansion.

Source: Frost & Sullivan



# Overview of the Hydrogen Energy Industry

## Overview of Global Hydrogen Energy Industry

### Europe

- In Europe, the development of the hydrogen energy industry has been strongly influenced by the EU's strategies and policies, particularly the European Green Deal announced in December 2019. The EU's Hydrogen Strategy, unveiled in July 2020, sets out the objective to produce up to 10 million tonnes of renewable hydrogen in the EU. In March 2023, the European Commission launched the European Hydrogen Bank to stimulate and support the production and investment of sustainable hydrogen energy. EUR3 billion is planned to be invested to help build the future market for hydrogen. In addition, European Hydrogen Bank will provide hydrogen production subsidies of up to EUR4.5/kg in the form of an auction around selected pilot projects, which can operate for up to 10 years. Germany, France and the Netherlands have also announced ambitious hydrogen strategies and funding initiatives. Germany's National Hydrogen Strategy was released in June 2020, targeting the establishment of a domestic hydrogen economy and aiming to become a global leader in hydrogen technologies. In July 2023, Germany's National Hydrogen Strategy set the goal of reaching 10GW capacity for domestic hydrogen production through water electrolysis. The country anticipates that hydrogen imports will constitute 50-70% of the total hydrogen supply by 2030. Furthermore, Germany plans to enhance international collaboration and implement a dedicated strategy for hydrogen imports. France's National Hydrogen Strategy was released in December 2023, planning to achieve 6.5GW of low-carbon hydrogen capacity by 2030 and 10GW by 2035. The strategy also mentioned that France will invest EUR4 billion in subsidies over the next three years to support the deployment of 1GW of electrolysis water production capacity, and will further invest nearly EUR9 billion by 2030 to support the deployment of decarbonized hydrogen. Netherlands is a major hydrogen producer in Europe and has formed a relatively complete hydrogen energy ecosystem. The Netherlands' Hydrogen Vision and Strategy, released in March 2020, emphasizes the role of hydrogen in achieving "carbon neutrality" by 2050. Europe's hydrogen energy industry benefits from its strong renewable energy infrastructure, particularly in countries like Germany, which has substantial wind and solar power capacity. The region also boasts advanced technological capabilities and a well-established industrial base. The hydrogen energy industry in Europe is witnessing a growing trend towards cross-sectoral integration. In addition, the carbon trading (European Union Emissions Trading System) and carbon taxes in Europe provide financial incentives for reducing carbon emissions, which in turn drive investment and innovation in low-carbon hydrogen production technologies. Green hydrogen, produced through water electrolysis using renewable electricity, is gaining traction as a key enabler of decarbonization efforts. European countries are also exploring the potential of hydrogen blending in natural gas pipeline networks and deploying hydrogen fuel cell vehicles. As the industry continues to mature, investments in R&D, regulatory support, and international collaboration are expected to drive further advancements in the hydrogen energy industry across Europe.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Overview of Global Hydrogen Energy Industry

### Americas

- In the Americas, both the United States and Brazil are making significant strides in advancing their hydrogen energy industries. The United States released its Hydrogen Strategy in December 2020, focusing on increasing hydrogen production capacity, reducing costs, and promoting deployment across various sectors. Furthermore, various states within the U.S., such as California, have implemented their own hydrogen-related initiatives to support research, development, and deployment of hydrogen technologies. In June 2023, U.S. National Clean Hydrogen Strategy and Roadmap was issued and targeted to increase clean hydrogen production to 10 million tons per year by 2030. The policy provided a snapshot of hydrogen production, transport, storage, and use in the U.S. and presented a strategic framework for achieving large-scale production and use of clean hydrogen, examining scenarios for 2030, 2040, and 2050. In October 2023, the U.S. Department of Energy has announced the seven hydrogen hub projects in the country that are eligible for USD7 billion in federal investment. This funding aims to accelerate the commercial-scale deployment of low-cost, clean hydrogen as an alternative source of energy. Local characteristics of the hydrogen energy industry in the Americas include the abundance of renewable energy resources, such as wind, solar, and hydropower, which can be harnessed for green hydrogen production. Additionally, both the United States and Brazil possess robust industrial bases and innovation ecosystems conducive to technology development and commercialization. As awareness of hydrogen's potential as a low-carbon and versatile energy carrier continues to grow, the Americas are poised to play a significant role in shaping the global hydrogen economy.

### Brazil

- Brazil is also leveraging its abundant renewable resources to drive the development of its low-carbon hydrogen industry. The three-year action plan (2023-2025) under the National Hydrogen Program sets ambitious goals, aiming to establish low-carbon hydrogen pilot plants across all regions of Brazil by 2025. The Ministry of Mines and Energy (MME) in Brazil estimates the country's technical potential to produce 1.8 gigatons of hydrogen annually at a lower production cost. Brazil's National Hydrogen Program exemplifies the country's dedication to spearheading the global energy transition. Through a multi-faceted strategy, ambitious targets, and active engagement with international partners, Brazil is well-positioned to emerge as one of the prominent players in the hydrogen industry.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

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### North Africa

- North African countries are also focusing on domestic green hydrogen production with the intent to export green hydrogen to countries committed to reducing carbon emissions. For example, Morocco's National Hydrogen Strategy outlines a roadmap towards a hydrogen-based economy by 2050. In the short term, from 2020 to 2030, Morocco aims to use hydrogen as a feedstock for the local production of green ammonia. Between 2030 and 2040, Morocco anticipates scaling up green hydrogen, green ammonia, and synthetic fuel production for both domestic use and export. By 2050, the strategy envisions a globalized hydrogen market in Morocco and domestic hydrogen utilization across industrial, residential, and transportation sectors.

Source: Frost & Sullivan



# Overview of the Hydrogen Energy Industry

## Overview of Global Hydrogen Energy Industry

### Australia

- In Australia, the development of the hydrogen energy industry is gaining momentum with the unveiling of various national policies and plans aimed at capitalizing on the country's abundant renewable energy resources and driving economic growth. One of the key initiatives is the National Hydrogen Strategy, released in November 2019, which outlines the government's vision to position Australia as a leading global exporter of hydrogen and to stimulate domestic hydrogen demand. The strategy focuses on establishing a hydrogen production and export industry, promoting R&D, and creating a supportive regulatory framework to facilitate industry growth. In July 2023, Hydrogen Headstart was released, aiming to expedite the growth of Australia's hydrogen industry, spur the development of clean energy sectors, facilitate Australia's integration into emerging global hydrogen supply chains and harness the substantial employment and investment opportunities presented by the hydrogen sector. Australia's hydrogen energy industry has vast renewable energy potential, particularly solar and wind resources, which can be leveraged for large-scale green hydrogen production through water electrolysis. Additionally, Australia possesses extensive experience in natural resource extraction and export, providing a strong foundation for developing a hydrogen export industry. The hydrogen energy industry in Australia is experiencing several notable trends, including increasing investments in hydrogen projects and infrastructure, both domestically and for export purposes. Government funding initiatives are supporting the development of hydrogen projects across the value chain, from production to transportation and utilization. Furthermore, partnerships between industry players, research organizations, and international counterparts are fostering innovation and knowledge exchange, positioning Australia as a key player in the global hydrogen market.

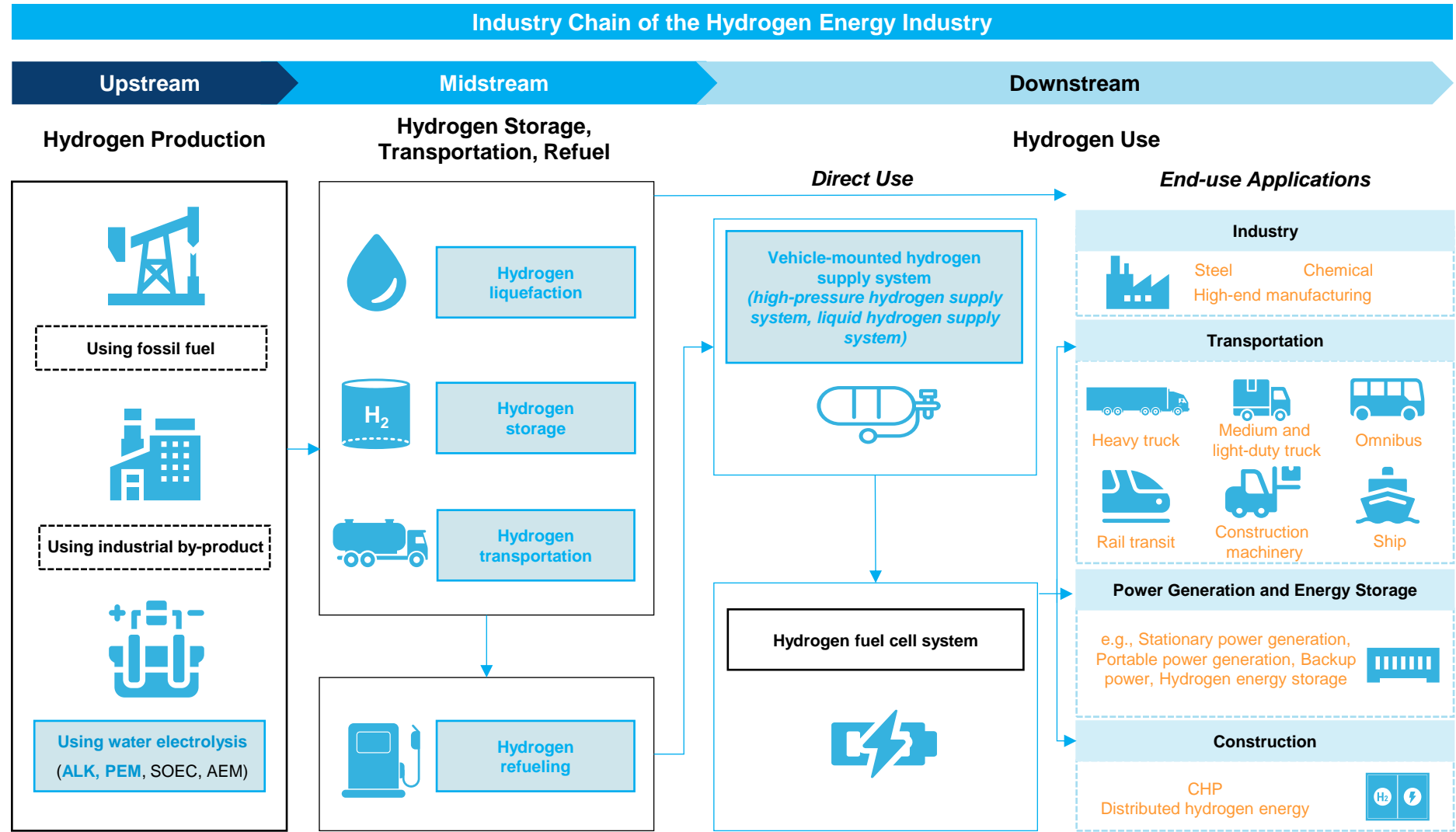
Driven by the strategic blueprint for hydrogen energy development in major economies worldwide, prominent hydrogen energy equipment manufacturing companies in China are proactively seeking global opportunities while delving deeply into local markets. Leveraging their advantages in competitive product costs, well-established supply chain systems, and robust R&D and production capabilities, these Chinese companies are effectively delivering hydrogen energy equipment solutions to overseas markets, thus driving the commercial adoption of hydrogen energy while enhancing their global influence in the hydrogen industry. For example, we've expanded our presence in the global hydrogen energy market by selling products directly and forming partnerships in regions such as Europe, Southeast Asia, the Americas, the Middle East, and Australia. These leading companies strategically integrate their inherent strengths with the attributes of overseas markets by offering core equipment of the hydrogen energy industry such as water electrolysis hydrogen production equipment, hydrogen refueling station equipment, vehicle-mounted high-pressure hydrogen supply systems, and liquid hydrogen equipment to international markets. Through the overseas deployment of these leading companies, they facilitate the ecological development of local hydrogen energy industries, drive the commercial adoption of hydrogen energy, and expedite the global implementation of carbon reduction targets.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Overview of Hydrogen Energy Industry

- The hydrogen energy industry can be segmented into upstream (i.e., production of hydrogen), midstream (i.e., storage, transportation and refuel of hydrogen) and downstream (i.e., application of hydrogen).



# Overview of the Hydrogen Energy Industry

## Industry Landscape of Hydrogen Energy Industry (1/2)

### ***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 and coal) or industrial by-products. Grey hydrogen is currently the most common hydrogen in China (approximately 96% of total). In 2023, fossil fuel (approximately 75%) was the main source in the production of hydrogen, followed by industrial by-products (approximately 21%). Blue hydrogen refers to hydrogen produced from fossil fuels in combination with carbon capture, utilization and storage (“CCUS”) technology, which can achieve low or zero carbon emission in the overall hydrogen production process. Blue hydrogen still relies on fossil fuels as raw materials. The current cost of CCUS technology is relatively high, so it has not yet been applied on a large scale. Green hydrogen, produced through water electrolysis powered by renewable energy, such as solar, wind and hydro power, represents a pivotal advancement in sustainable energy. Downstream applications of green hydrogen span diverse industries, including chemicals, metallurgy and transportation, showcasing its versatility as a clean energy carrier. It is expected that the proportion of green hydrogen in China will increase from less than 5% in 2023 to approximately 20% of the total hydrogen production volume by 2030.

### ***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. At present, high-pressure gaseous hydrogen storage and cryogenic liquid hydrogen storage have entered a commercial application stage, while organic liquid hydrogen storage and solid material hydrogen storage are still in the pilot demonstration stage. 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 will be increasingly applied in the future.

### ***Hydrogen Transportation***

Depending on the different storage methods, hydrogen can be transported in gaseous, liquid and solid forms. The transportation of gaseous hydrogen through tube trailers and pipelines is currently the major 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 the characteristics of long pipeline construction period, large investment, and complicated approval process. Liquid hydrogen can be transported by liquid hydrogen tankers and liquid hydrogen tanks, of which hydrogen tanks have the advantage of intermodal transportation, and its storage and transportation can significantly improve hydrogen transport efficiency for large-capacity and long-distance hydrogen transportation. For transportation distances below 200 kilometers, tube trailer transportation of gaseous hydrogen holds a cost advantage. For transportation distances exceeding 200 kilometers, there is a cost advantage for transporting liquid hydrogen via liquid hydrogen tanks and tankers due to high-energy and volume density of liquid hydrogen.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Industry Landscape of Hydrogen Energy Industry (2/2)

### ***Hydrogen Downstream Application***

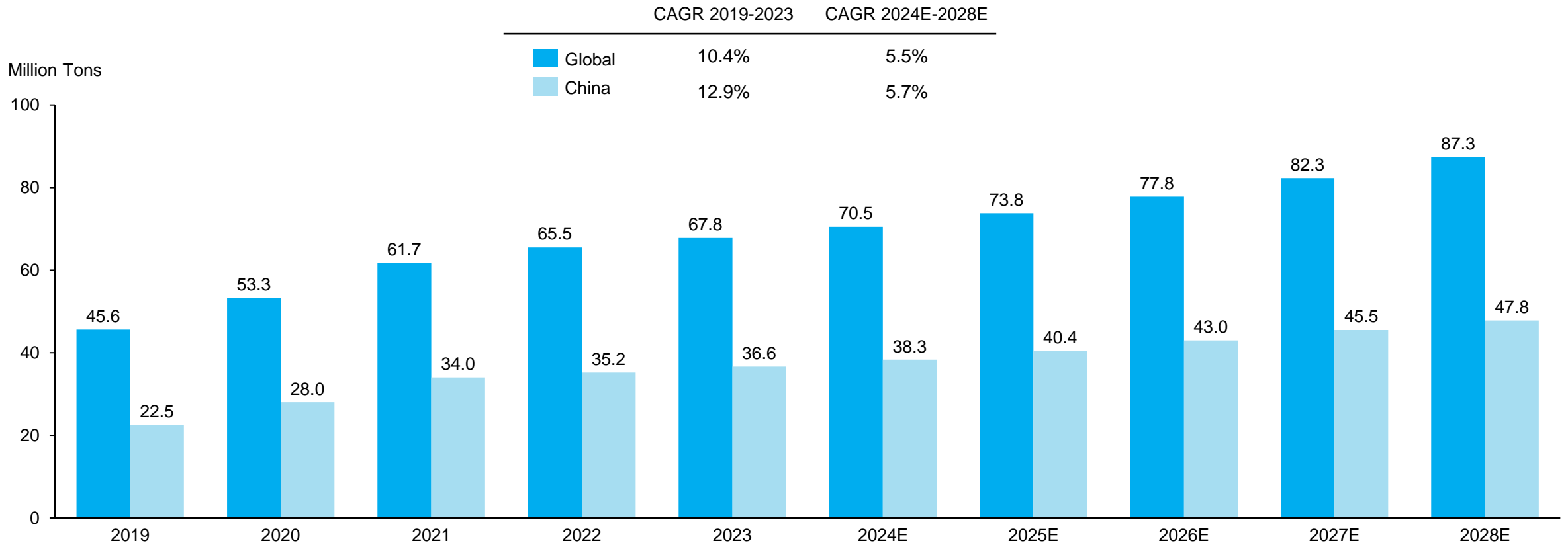
The downstream applications of hydrogen can be further categorized based on specific utilization scenarios. With continuous industrial development, hydrogen plays a pivotal role as a vital industrial raw material, catering to stable and mature demand markets. Notably, the industrial sector represents the largest consumption segment of hydrogen in China. Looking ahead, driven by favorable policies, the transportation sector is poised to offer extensive commercial market opportunities. In order to capitalize on this potential, vehicle manufacturers and upstream core equipment and component suppliers need to consistently prioritize technological advancements, enhance product quality and reduce costs. These efforts are essential to attract more downstream customers and encourage the widespread adoption of hydrogen fuel cell vehicles in the transportation sector. In addition, hydrogen will also be applied in the fields of power generation and energy storage, such as hydrogen blending in natural gas pipeline networks, distributed heat and power cogeneration, hydrogen energy storage and hydrogen-electricity coupling.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Market Size Analysis of Hydrogen

Consumption Volume of Hydrogen (Global and China), 2019-2028E



- The global and China's hydrogen consumption volume increased from 45.6 million tons and 22.5 million tons in 2019 to approximately 67.8 million tons and 36.6 million tons in 2023 at CAGRs of 10.4% and 12.9%, respectively, and is expected to reach approximately 87.3 million tons and 47.8 million tons in 2028, respectively.

# Overview of the Hydrogen Energy Industry

## Drivers and Trends of the Global and China's Hydrogen Energy Industry

### **Favourable policies to support the development of hydrogen energy industry**

Governments globally are actively pursuing the objective of “carbon neutrality” and have implemented a series of policies to promote the development of clean energy. As an important measure to tackle climate change and accelerate energy transformation, more economies attach great importance to the development of the hydrogen energy industry and regard it as a part of the energy development strategy. Notably, green hydrogen has become an emerging pivotal strategy to achieve “carbon neutrality”, facilitate the transition to low-carbon energy sources, enhance energy security and modernize traditional industries.

### **Market demand continues to increase**

Driven by global promotion of decarbonization and sustainable energy solutions, the demand for hydrogen energy increased significantly. The increasing demand is propelled by (i) advancements in hydrogen production technologies such as water electrolysis. Water electrolysis, especially when coupled with renewable energy sources such as wind and solar power, enables the production of green hydrogen with minimal carbon emissions, further enhancing its appeal in the transition to a low-carbon economy; and (ii) the nature of a versatile energy carrier that is capable of powering various sectors. In transportation, hydrogen fuel cell vehicles offer a promising alternative to internal combustion engines, providing long driving ranges and fast refueling times. Similarly, in industries such as steel manufacturing, ammonia production and chemical processing, hydrogen serves as a low-carbon alternative to carbon-intensive processes, facilitating the reduction of greenhouse gas emissions. Furthermore, in the realm of power generation and energy storage, the capacity for large-scale, extended-duration energy storage offered by hydrogen presents a new path for tackling the disparities between power supply and demand. Moreover, hydrogen is expected to serve as a promising solution for ensuring reliable power provision to critical scenarios such as data centers, telecommunications towers, hospitals, and emergency response systems. The demand for hydrogen energy will continue to grow in a foreseeable future in light of these growing number of applications.

### **Technology development**

The development of hydrogen technologies has undergone thorough research and validation, focusing on cleaner, safer and more economical approaches. The technology breakthroughs improve the efficiency and safety of the production, storage, transportation, refueling and use of hydrogen energy. The technology advancements also contribute to domestication and cost reduction of hydrogen energy industry. In particular, as China's independent production capability of core equipment and components of the hydrogen energy industry continues to improve, leading hydrogen energy equipment manufacturers will begin to explore broader development opportunities in overseas hydrogen energy markets while deeply exploring the China's market.

Source: Frost & Sullivan



# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

In recent years, the relevant government authorities in China have issued a number of favorable policies and documents to support the development of hydrogen energy industry and related sub-industries, which became the key drivers for the development of China's hydrogen energy industry and thereby, directly benefiting all stakeholders in the industry value chain, including core equipment manufacturers like our Company, as well as our customers (e.g. hydrogen fuel cell vehicle manufacturers and hydrogen fuel cell system manufacturers).

These supportive policies and documents underscore the strategic importance of hydrogen energy within the energy system, ensuring national energy security and facilitating the transition towards a green and low-carbon energy structure. Such policies and documents encourage the coordinated development of hydrogen energy across its entire value chain, spanning production, storage, transportation and use. This emphasis aims to bolster the competitiveness of the hydrogen energy sector as a whole. Furthermore, the relevant government authorities in China have been committed to the orderly advancement of infrastructure for the hydrogen energy industry, expediting the establishment of a safe, stable and efficient hydrogen energy network. This involves enhancing equipment manufacturing capabilities and fortifying the hydrogen energy supply system. Moreover, the Chinese government incentivized the demonstration applications of hydrogen energy across various sectors, thereby catalyzing its commercialization. There has been substantial support for the innovation of key technologies throughout the research, development, and application phases of the hydrogen energy value chain. Additionally, the exploration of diverse pathways for key technologies pertaining to hydrogen energy core equipment will be pursued vigorously. These related policies have geared towards establishing a comprehensive system of the hydrogen energy industry standard to drive the sustainable development of the hydrogen energy industry.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

The following sets forth the key supportive policies and documents relating to the entire hydrogen energy industry in China:

- “2024 Government Work Report” (《2024政府工作報告》) was released by the Chinese government in March 2024. The report proposed to actively cultivate emerging industries and future industries, consolidate and expand the leading advantages of industries such as intelligent connected new energy vehicles, and accelerate the development of cutting-edge emerging industries, including hydrogen energy industry.
- “Green and Low-Carbon Transformation Industry Guidance Catalog (2024 Edition)” (《綠色低碳轉型產業指導目錄(2024年版)》) was issued by seven national departments of China, including the NDRC and the MIIT, in March 2024. A new special guidance catalog for the entire hydrogen energy industry chain was added, expanding the scope of hydrogen energy infrastructure. Meanwhile, hydrogen production and hydrogen production equipment were included in the catalog.
- “Guiding Opinions on Accelerating the Green Development of the Manufacturing Industry” (《關於加快推動製造業綠色化發展的指導意見》) was issued by seven national departments of China, including the MIIT, in February 2024. The document proposed to build a complete hydrogen energy technology and equipment system for hydrogen production, storage, transportation and application in the fields of petrochemicals, steel, transportation, energy storage and power generation.
- “Standardized Construction Guidelines for the Hydrogen Industry (2023)” (《氫能產業標準體系建設指南(2023版)》) was issued by the SAC, the NDRC, the MIIT and other three official authorities in August 2023. The publication of the guidelines marked a milestone process of standardization of China’s hydrogen energy industry and provide a three-year roadmap for standardizing the entire production, storage, transportation and use of hydrogen through clear goals for six sub-sectors.
- “Energy Carbon Peak Carbon Neutral Standardization Promotion Action Plan” (《能源碳達峰碳中和標準化提升行動計劃》) was published by the National Energy Administration in October 2022. It proposed to further promote the standardized management of the development of the hydrogen energy industry, and accelerate the improvement of the top-level design and standard system of hydrogen energy standards.
- “Medium and Long-term Development Plan for Hydrogen Industry (2021-2035)” (《氫能產業發展中長期規劃(2021-2035年)》) was issued by the NDRC and the National Energy Administration in March 2022. It clarified the strategic position of hydrogen energy as an important part of the future national energy system, an important carrier for achieving green and low-carbon transformation, and a strategic emerging industry and a key development direction for future industries.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

- “14th Five-Year Renewable Energy Development Plan” (《“十四五”可再生能源發展規劃》) was issued by the NDRC, the MIIT and other seven national departments in October 2021. It proposed to strengthen the R&D of frontier technologies such as energy storage and hydrogen energy, and to put forward the requirements for the R&D of key technologies and diversified pilot applications in the field of hydrogen energy such as the preparation, storage and transportation of hydrogen.
- “Energy Law of the People’s Republic of China (Draft for Comments)” (《中華人民共和國能源法(徵求意見稿)》) was published by the National Energy Administration in April 2019. Hydrogen energy is officially included in the legal definition of energy for the first time.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

### ***Favorable Policies and Documents Relating to the Vehicle-mounted High-pressure Hydrogen Supply Systems and Hydrogen Storage Cylinders Industry***

The national and local governments' supportive policies, such as the relevant "award in lieu of subsidy" (以獎代補) policies and the subsidy policies before 2020, were key in promoting the development of the hydrogen fuel cell vehicles industry by providing incentives to the hydrogen fuel cell vehicle manufacturers, and directly benefiting the relevant component and equipment manufacturers in the value chain, including the manufacturers of vehicle-mounted high-pressure hydrogen supply systems and hydrogen storage cylinders, as well as hydrogen fuel cell systems manufacturers. These policies stimulated the promotion of hydrogen fuel cell vehicles by providing financial support and encouraging the formation of the relevant demonstration city clusters in China. Additionally, such policies clearly stated the plans and goals of the hydrogen fuel cell vehicles industry in the medium and long-term development to guide market participants. Some local governments are also actively introducing favorable policies, such as temporarily exempting highway toll fees, to promote the adoption of hydrogen fuel cell vehicles.

The following sets forth the key supportive policies and documents relating to the vehicle-mounted high-pressure hydrogen supply systems and hydrogen storage cylinders industry in China:

- *"Notice on the Temporary Exemption of Toll Fees for Hydrogen Vehicles on High-speed Highways"* (《關於對氫能車輛暫免收取高速公路通行費的通知》) was issued by the Department of Transportation and other related official authorities of Shandong Province in February 2024. The policy allowed that hydrogen vehicles equipped with ETC equipment driving on high-speed highways in Shandong Province to be temporarily exempted from highway tolls. The policy was implemented on March 1, 2024 with a trial period of two years, which is expected to promote the demand for hydrogen fuel cell vehicles.
- *"Medium and Long-term Development Plan for Hydrogen Industry (2021-2035)"* (《氫能產業發展中長期規劃(2021-2035年)》) was issued by the NDRC and the National Energy Administration in March 2022. It aimed that by 2025, the number of hydrogen fuel cell vehicles will reach approximately 50,000 units.
- *"14th Five-Year Plan for the Development of Modern Integrated Transport System"* (《“十四五”現代綜合交通運輸體系發展規劃》) issued by the State Council in December 2021. The policy proposed to promote low-carbon and diversified energy of transportation sector, actively promote new energy and clean energy transportation vehicles, and further reduce energy consumption of transportation. In addition, the policy proposed to select suitable areas to build near-zero carbon transportation demonstration zones, prioritize the development of public transportation, advocate green travel and promote new energy transportation tools.
- *"Implementation Plan for the Promotion of Green Consumption"* (《促進綠色消費實施方案》) was issued by the State Council in January 2021. The policy proposed to vigorously develop green transportation consumption, orderly carry out demonstration applications of hydrogen fuel cell vehicles, and build supporting infrastructure such as hydrogen refueling stations.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

- “*Notice on Launching the Pilot Application of Fuel Cell Vehicles*” (《關於開展燃料電池汽車示範應用的通知》) issued by the MOF, the MIIT, the Ministry of Science and Technology, the NDRC and the National Energy Administration in September 2020. It proposed to adopt the “award in lieu of subsidy” (以獎代補) policy to the cities that meet hydrogen fuel cell vehicle demonstration requirements to further promote the application of hydrogen fuel cell vehicles, and clarified specific application requirements for the demonstration city clusters. By the end of 2023, five demonstration city clusters have passed the approval by the PRC government.
- “*Notice on Improving the Policies of Government Subsidies for Promotion and Application of New Energy Vehicles*” (《關於完善新能源汽車推廣應用財政補貼政策的通知》) issued by the MOF, the MIIT, the Ministry of Science and Technology and the NDRC in April 2020. It proposed to adopt the “award in lieu of subsidy” (以獎代補) policy to give incentives to the demonstration city clusters, which will reward eligible city clusters for the commercialization of key technologies used in the hydrogen fuel cell vehicles and the pilot adoption of hydrogen fuel cell vehicles within the city clusters instead of directly providing subsidies. The policy also proposed to establish relatively mature hydrogen energy and hydrogen fuel cell vehicle value chains in four years with breakthroughs in key core technologies.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

### ***Favorable Policies and Documents Relating to the Core Equipment for Hydrogen Refueling Stations Industry***

The relevant government authorities in China have provided supportive policies and documents to promote the construction of hydrogen refueling stations, which stimulated the expansion of the hydrogen refueling stations network across the country over the past few years, and directly benefited the relevant core equipment manufacturers for hydrogen refueling stations. These supportive policies and documents have put forward clear plans and set targeted goals for the development of hydrogen refueling stations in China (e.g. build 1,000 hydrogen refueling stations by 2025 and 5,000 hydrogen refueling stations by 2030 to 2035). In addition, the relevant policies proposed to support the use of existing gas station facilities to reconstruct and expand hydrogen refueling stations, and explore new models such as hydrogen refueling stations that integrate hydrogen production, storage and refueling within the station, which are expected to drive the innovation and upgrade of the technologies of core equipment for hydrogen refueling stations industry in China.

The following sets forth the key supportive policies relating to the core equipment for hydrogen refueling stations industry in China:

- “*Medium and Long-term Development Plan for Hydrogen Industry (2021-2035)*” (《*氢能產業發展中長期規劃(2021-2035年)*》) was issued by the NDRC and the National Energy Administration in March 2022. This policy set the goal of deploying and constructing a number of hydrogen refueling stations by 2025.
- “*Action Plan for Carbon Peaking Before 2030*” (《*2030年前碳達峰行動方案*》) was issued by the State Council in October 2021. The document encouraged to promote the construction of charging piles, supporting power grids, filling (gas) stations, hydrogen refueling stations and other infrastructure in an orderly manner to improve the level of urban public transportation infrastructure.
- “*Energy-Saving and New Energy Vehicle Roadmap 2.0*” (《*節能與新能源汽車路線2.0*》) was issued by the China Society of Automotive Engineers in October 2020. It proposes to build 1,000 hydrogen refueling stations by 2025 and 5,000 hydrogen refueling stations by 2030-2035 in China.

Source: Frost & Sullivan



# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

### ***Favorable Policies and Documents Relating to the Core Equipment for Liquid Hydrogen Industry***

Due to the absence of comprehensive standards and relevant regulations, the utilization of liquid hydrogen in China has been primarily confined to the aerospace and military sectors for an extended period. In November 2021, the Chinese government unveiled three national standards specifically for liquid hydrogen, encompassing its production, storage, transportation and use. With the establishment and enhancement of these liquid hydrogen standard frameworks, manufacturers of core equipment for liquid hydrogen in China are poised to intensify their R&D efforts and expedite the localization process of core equipment, thereby facilitating the widespread deployment of liquid hydrogen in China in the future.

The following sets forth the key supportive policies relating to the core equipment for liquid hydrogen industry in China:

- *GB/T 40045-2021 “Hydrogen Fuel for Hydrogen-Powered Vehicles-Liquid Hydrogen”* (GB/T40045-2021 《氢能汽车用燃料液氢》) was issued by the Standard Administration of State Administration for Market Regulation and implemented in November 2021. It provided technical indicators, testing methods, and requirements for storage and transportation of liquid hydrogen as a fuel for hydrogen-powered vehicles.
- *GB/T 40060-2021 “Technical Requirements for Storage and Transportation of Liquid Hydrogen”* (GB/T40060-2021 《液氢贮存和运输技术要求》) was issued by the Standard Administration of State Administration for Market Regulation and implemented in November 2021. It specified requirements for the installation of fixed storage tanks, transportation using mobile tankers, container purging, replacement and safety operations in the process of civil storage and transportation of liquid hydrogen.
- *GB/T40061-2021 “Technical Specifications for Liquid Hydrogen Production Systems”* (GB/T40061-2021 《液氢生产系统技术规范》) was issued by the Standard Administration of China and implemented in November 2021. It outlined the basic configuration requirements for civilian liquid hydrogen production systems, including hydrogen liquefaction units, tank configurations, hydrogen emissions, etc.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

### ***Favorable Policies and Documents Relating to the Water Electrolysis Hydrogen Production Equipment Industry***

The Chinese government has implemented a comprehensive set of policies aimed at fostering the advancements in water electrolysis technology and promoting the utilization of renewable energy sources for hydrogen production. Concurrently, in alignment with the government's initiatives to bolster the water electrolysis industry, several local governments have eased restrictions on both production and installation of water electrolysis hydrogen production. Such supportive measures are poised to promote the increasing demand for hydrogen produced from renewable energy, thus yielding substantial benefits for equipment manufacturers of the water electrolysis hydrogen production industry. As a result, these manufacturers are expected to experience significant growth opportunities and enhanced market competitiveness, driving further innovation and development within the industry.

The following sets forth the key supportive policies relating to the water electrolysis hydrogen production equipment industry in China:

- *“Notice on Accelerating the Development of the Hydrogen Energy Industry”* (《關於加快推進氫能產業發展的通知》) was issued by the authorities of Inner Mongolia Autonomous Region in February 2024. The document allowed (i) water electrolysis hydrogen production projects with renewable energy sources as well as hydrogen production and refueling stations to be constructed outside the chemical industry park and; (ii) water electrolysis hydrogen production projects with renewable energy sources do not need to obtain the safety production license for hazardous chemicals in the Inner Mongolia Autonomous Region.
- *“Blue Book on the Development of New Power Systems”* (《新型電力系統藍皮書》) was issued by the National Energy Administration in June 2023. The document encouraged breakthroughs in key technologies applicable to renewable energy electrolysis for hydrogen production, including proton exchange membrane (“PEM”).
- *“Medium and Long-term Development Plan for Hydrogen Industry (2021-2035)”* (《氫能產業發展中長期規劃(2021-2035年)》) was issued by the NDRC and the National Energy Administration in March 2022. By 2025, the fleet of hydrogen fuel cell vehicles was aimed to reach approximately 50,000 units, with the deployment and construction of a number of hydrogen refueling stations, and hydrogen produced from renewable energy will reach 100,000 to 200,000 tons per year.
- *“14th Five-Year Plan for Renewable Energy Development”* (《“十四五”現代能源體系規劃》) was issued by the NDRC and the National Energy Administration in March 2022. The policy proposed to strengthen research on cutting-edge technologies such as energy storage and hydrogen energy, focus on core technologies such as renewable energy hydrogen production and hydrogen energy storage, transportation, and application, and strive to achieve breakthroughs in key technologies throughout the hydrogen energy industry chain.
- *“14th Five-year Plan for Implement Plan for the Development of New Energy Storage”* (《“十四五”新型儲能發展實施方案》) was issued by the NDRC and the National Energy Administration in January 2022. This document proposed to increase R&D efforts on key technologies and equipment for hydrogen energy storage. In addition, the policy proposed to carry out demonstration applications of hydrogen energy storage such as renewable energy production and storage of hydrogen and hydrogen-electric coupling.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Favorable Policies and Documents in China

- “*Guiding Opinions on Promoting the Integration of Power Generation, Grids, Demand, and Storage & the Development of Multi-energy Complementarity*” (《關於推進電力源網荷儲一體化和多能互補發展的指導意見》) was issued by the NDRC and the National Energy Administration in February 2021. It proposed to build a clean, safe and efficient energy system, improve the clean energy utilization and the efficiency of power system operation.

Source: Frost & Sullivan

# Overview of the Hydrogen Energy Industry

## Overview of the Five Hydrogen Fuel Cell Vehicle Demonstration City Clusters

By the end of 2022, five demonstration city clusters have passed the approval by the PRC government, and the vehicle types include fuel cell passenger vehicles, light and heavy trucks, commercial buses, etc. The five demonstration city clusters that have been passed the approval by the PRC government so far are mainly developed cities and regions in China. The five city clusters set a relatively early foot in the field of hydrogen fuel cell vehicle market, which has solid industrial foundation, relatively strong scientific research strength, and rich application scenarios. Guided by the demonstration city clusters, the development of the hydrogen fuel cell vehicle market as well as the relevant hydrogen fuel cell core component industries and infrastructure will gradually radiate to the surrounding areas, indicating that the PRC government plans to break through the restrictions of cities and administrative districts, which is conducive to the formation of the hydrogen energy industry clusters with regional characteristics as well as a national-wide hydrogen fuel cell industry chain.

Demonstration City Cluster	Lead Cities	Participating Cities and Areas	Approved time	Targets	Progress (as of August 31, 2023)
Shanghai City Cluster	Shanghai	Suzhou, Nantong, Jiaxing, Zibo, Ningdong, Ordos	2021.09	Promote 10,000 fuel cell vehicles and 100 hydrogen refueling stations	Promoted 4,000+ fuel cell vehicles and built 26 hydrogen refueling stations, representing over a progress of 40% and 37%, respectively
Beijing-Tianjin-Hebei City Cluster	Beijing (Daxing District, Haidian District, Beijing Economic- technological Development Area District, Yanqing District, Shunyi District, Fangshan District, Changping District)	Tianjin Binhai New Area, Tangshan, Baoding, Binzhou, Zibo	2021.09	Promote 5,300 fuel cell vehicles and 49 hydrogen refueling stations	Promoted 2,500+ fuel cell vehicles and built 30 hydrogen refueling stations, representing a progress of over 47% and 61%, respectively
Guangdong City Cluster	Foshan	Guangzhou, Shenzhen, Dongguan, Zhuhai, Zhongshan, Yangjiang, Yunfu, Fuzhou, Zibo, Baotou, Lu'an	2021.09	Promote 10,000 fuel cell vehicles and 200 hydrogen refueling stations	Promoted 3,200+ fuel cell vehicles and built 56 hydrogen refueling stations, representing a progress of over 32% and 28%, respectively
Henan City Cluster	Zhengzhou	Luoyang, Xinxiang, Kaifeng, Anyang, Jiaozuo, Jiading District, Shanghai, Fengxian District, Shanghai, Lin-gang Special Area of China (Shanghai) Pilot Free Trade Zone, Zhangjiakou, Baoding, Xinji, Yantai, Zibo, Weifang, Foshan, Ningdong Town, Ningxia Hui Autonomous Region	2022.01	Promote 5,000 fuel cell vehicles and 80 hydrogen refueling stations	Promoted 1,200+ fuel cell vehicles and built 28 hydrogen refueling stations, representing a progress of 24% and 35%, respectively
Hebei City Cluster	Zhangjiakou	Tangshan, Baoding, Handan, Qinhuangdao, Dingzhou, Xinji, Xiongan New Area, Wuwei, Inner Mongolia Autonomous Region, Fengxian District, Shanghai, Zhengzhou, Zibo, Liaocheng, Xiamen	2022.01	Promote 7,710 fuel cell vehicles and 100 hydrogen refueling stations	Promoted 1,100+ fuel cell vehicles and built 18 hydrogen refueling stations, representing a progress of over 14% and 18%, respectively

# Overview of the Hydrogen Energy Industry

## Policies and Regulations(1/2)——Global

Policy	Release Date	Issuing Agency/Country	Content
REPowerEU Plan	2023.03	EU	The plan scales up electrolyzers with the intent to overcome the current bottleneck in clean hydrogen production and distribution, creating a robust, as well as a dedicated "Hydrogen Bank" that is meant to attract private investment and bridge the commercialization gap for promising hydrogen technologies.
Clean Hydrogen Future Strategy and Roadmap	2023.06	The U.S.	It prioritizes renewable hydrogen production, infrastructure development, and demand stimulation for fuel cell vehicles and various sectors, aiming for 1 million carbon-free vehicles and 10 million tons of clean hydrogen by 2030. Benefits offered include significant tax credits, tax breaks and solid funding.
National Green Hydrogen Mission	2023.07	India	Key pillars of the plan include financial incentives for renewable green hydrogen production, demand stimulation through mandatory green hydrogen blending in key industries, as well as domestic Manufacturing and Technology Development support.
Hydrogen Economy Development Strategy	2022.11	Korea	The Korean government held the first meeting of the hydrogen economy committee after the establishment of the new government on the 9th and announced the new direction of the hydrogen economy policy.
U.S. Inflation Reduction Act	2022.08	The U.S.	It proposes a tax credit for green hydrogen, which can be as high as US \$0.6 per kilogram, of which the tax credit for green hydrogen is US \$3 per kilogram, while the tax credit for "blue" and "hydrogen" is sharply reduced.
The Road Map of South Africa's Hydrogen Energy Social Network	2022.02	South Africa	It proposed to establish a green hydrogen and ammonia export market by providing energy storage and power supply services to the main power grid, hydrogen energy helps the power industry achieve decarbonization and enhance the stability of the power grid. In the next 10 years, the capacity of the electrolyzer will reach several GW, and the gas and ammonia will be used for turbine power generation. In 2040, the capacity of the electrolyzer will reach at least 15GW.
Guidelines for International Hydrogen Energy Project Funding	2021.10	Germany	It promoted the construction of overseas hydrogen energy projects, accelerate the development of hydrogen energy economy and prepare for the import of German hydrogen energy.

# Overview of the Hydrogen Energy Industry

## Policies and Regulations(2/2)——Global

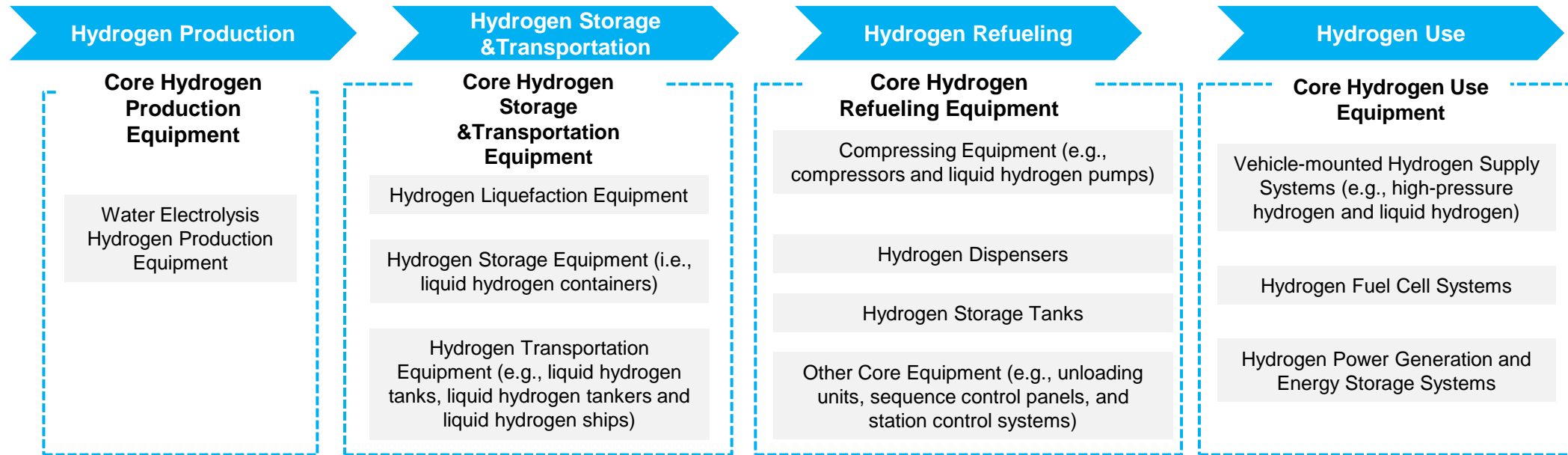
Policy	Release Date	Issuing Agency/Country	Content
The EU Hydrogen Strategy	2020.07	EU	It supports deploying 40 GW of electrolyzer capacity by 2030, fostering the decarbonization of hard-to-abate sectors such as international shipping or steel and cement production.
Road Map to a US Hydrogen Economy	2019.11	the U.S.	It reiterated that it will continue to maintain its dominant technological position in the field of hydrogen energy; expand the scale application of hydrogen energy in several fields such as transportation, distributed power supply and domestic cogeneration; and proposed to reach 5.3 million fuel cell vehicles and 5,600 hydrogen refueling stations by 2030.
Australia's National Hydrogen Strategy	2019.11	Australia	It sets a path to build Australia's hydrogen industry. Australian government plans to accelerate the commercialization of hydrogen, reduce technical uncertainties and build up our domestic supply chains and production capabilities. It looks to initially concentrate hydrogen use in niche hubs that will foster domestic demand.
Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition	2019.02	EU	It stated that hydrogen energy is essential for Europe to achieve its decarbonization goals and that hydrogen energy will play a role in large-scale decarbonization of buildings, transport and industry. And it predicted that hydrogen energy will account for 25% of Europe's total energy demand by 2050.
Roadmap for the Strategic Development of Hydrogen Energy and Fuel Cells	2019.03	Japan	It proposed the goals of fully popularizing hydrogen transportation, commercializing hydrogen power generation, and significantly reducing the cost of hydrogen energy utilizing by 2025.
Roadmap for Hydrogen Economy Development	2019.01	Korea	It added hydrogen energy industry as one of the three strategic investment areas, and hydrogen fuel cell vehicles and fuel cells remain a strategic focus: it proposes to popularize hydrogen fuel cell devices for power generation, households and buildings by 2040; it proposed to invest \$51 million in the next five years to support hydrogen production and storage technology, and \$2.33 billion for infrastructure construction and fuel cell system development.



# Overview of the Hydrogen Energy Industry

## Definition of Hydrogen Energy Core Equipment

- Hydrogen energy core equipment refers to the devices and technologies crucial in various processes of the industrial value chain of hydrogen energy, including production, storage, transportation, refueling and use of hydrogen energy. Hydrogen energy core equipment plays a key role in advancing the commercialization and application of the technologies in relation to hydrogen energy.
- The following diagram illustrates the hydrogen energy core equipment used in the entire value chain of the hydrogen energy industry:



Leading industry players contribute to the growth of the hydrogen industry by expanding their presence into various processes of the industrial value chain, providing integrated solutions to customers that encompass the production, storage, transportation, refueling and use of hydrogen energy.

# Overview of the Hydrogen Energy Industry

## Core Competencies of the Market Players in Hydrogen Energy Core Equipment Industry

Companies thriving in the hydrogen energy core equipment industry distinguish themselves through a multitude of core competencies, which collectively contribute to their success and differentiate them from competitors:

### ***Robust R&D Capabilities***

- The hydrogen energy industry is in its early stage of development, with its industrial ecosystem awaiting further maturation. Leading companies in the hydrogen energy core equipment industry are seizing opportunities by leveraging their technological advantages in the relevant fields to establish an early presence in key segments of the industry, such as Type-IV cylinders, equipment for liquid hydrogen production and storage, equipment for 70MPa hydrogen refueling station and equipment for water electrolysis hydrogen production. Simultaneously, these frontrunners actively participate in the formulation of industry standards pertinent to the hydrogen energy core equipment industry. This engagement not only solidifies their early-mover advantage but also fosters a conducive environment for industry growth and standardization.

### ***Product Innovation and Production Capabilities***

- The ability to innovate products and enhance production capabilities is paramount in the hydrogen energy core equipment industry, as it reflects a company's adaptability in aligning product features with evolving downstream demands. For instance, with the increasing demand for longer range and higher capacity hydrogen fuel cell vehicles, manufacturers are witnessing an iteration in specifications for vehicle-mounted high-pressure hydrogen storage cylinders in China. Leading manufacturers are not only responding to these evolving demands by developing new products but also by ramping up their production capacities. Concurrently, they are investing in automation, digitization and intelligent management of production processes. This strategic progress facilitates cost reductions in manufacturing, enhances production efficiency and elevates product quality standards, thereby ultimately bolstering their competitive position in the market.

# Overview of the Hydrogen Energy Industry

## Core Competencies of the Market Players in Hydrogen Energy Core Equipment Industry

### ***Supply Chain Integration Capabilities***

- The integration of supply chains is another strategic advantage of the leading hydrogen energy core equipment manufacturers, marked by forming enduring partnerships with top-tier suppliers of hydrogen core equipment to facilitate the continuous technological evolution and upgrades in the hydrogen energy industry. Meanwhile, by embedding themselves within the industry supply chain and fostering R&D collaborations, these companies accelerate the domestication of key hydrogen energy components and technologies.

### ***Strong Relationship with High Quality and Stable Customers***

- Leading companies in the hydrogen energy core equipment industry leverage their deep industry knowledge and extensive experience to cultivate, sustain and expand their customer base. Their comprehensive reach across the demonstration city clusters of hydrogen fuel cell vehicles in China and partnerships with prominent entities in the energy sector, such as well-known energy companies, hydrogen fuel cell vehicle manufacturers and hydrogen fuel cell system manufacturers, among others, reinforce their industry impact and brand recognition, securing consistent demand for their products. Furthermore, leading companies in the hydrogen energy core equipment industry are capable of tailoring their products and services specifically to customer requirements, further extending their business reach and fostering customer loyalty.

### ***Forward-looking Strategic Approach***

- Leading industry players have developed forward-looking strategic layout by expanding their presence into various key stages of the industrial value chain of hydrogen energy industry, providing integrated solutions to customers that encompass the production, storage, transportation, refueling and use of hydrogen energy. Meanwhile, leveraging the advantages in the domestic market, some leading industry players are actively exploring the overseas markets to capture the growing opportunities in the global hydrogen energy industry. This expansive involvement propels the growth of the global hydrogen industry, solidifying the key positions of these companies within the industry chain of their suppliers and customers.

# Agenda

- 1 Overview of the Hydrogen Energy Industry
- 2 Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry**
- 3 Overview of Core Equipment for Hydrogen Refueling Station Industry
- 4 Overview of Core Equipment for Liquid Hydrogen Industry
- 5 Overview of the Water Electrolysis Hydrogen Production Equipment Industry
- 6 Appendix



# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Overview of Hydrogen Fuel Cell Vehicle

### Definition of Hydrogen Fuel Cell Vehicle

- Hydrogen fuel cell vehicle is a vehicle that uses a hydrogen fuel cell system as a single power source, or a hydrogen fuel cell system and a rechargeable energy storage system as a hybrid power source. The pivotal elements of hydrogen fuel cell vehicles encompass the vehicle-mounted hydrogen supply system and the hydrogen fuel cell system.
- The following table sets forth the comparison of hydrogen fuel cell vehicle with battery electric vehicle and internal combustion engine vehicle:

### Analysis of the Advantages of Hydrogen Fuel Cell Vehicle

Metric	Hydrogen Fuel Cell Vehicle	Electric Vehicle	Internal Combustion Engine Vehicle
<b>Mechanical system</b>	Fuel cell system	Lithium battery	Internal combustion engine
<b>Filling material</b>	Hydrogen	Electricity	Gasoline or diesel
<b>Environmental protection</b>	No carbon emission or pollution when operating the vehicle	Pollution partially transferred upstream	Emissions of greenhouse gases such as CO <sub>2</sub> , CO, SO <sub>2</sub> , etc.
<b>Mileage</b>	500-800 km	300-600 km	500-700 km
<b>Energy conversion rate</b>	40-60%	Not applicable	30-40%
<b>Infrastructure for refilling/charging services</b>	Hydrogen refueling station, filling time: 3-15min	Charging port, charging time: 30 min to 8 hours on average	Gas station, filling time: 5-10min
<b>Field of application</b>	Medium and long distance, heavy transportation	Short- and medium-distance transportation	Universally applicable

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

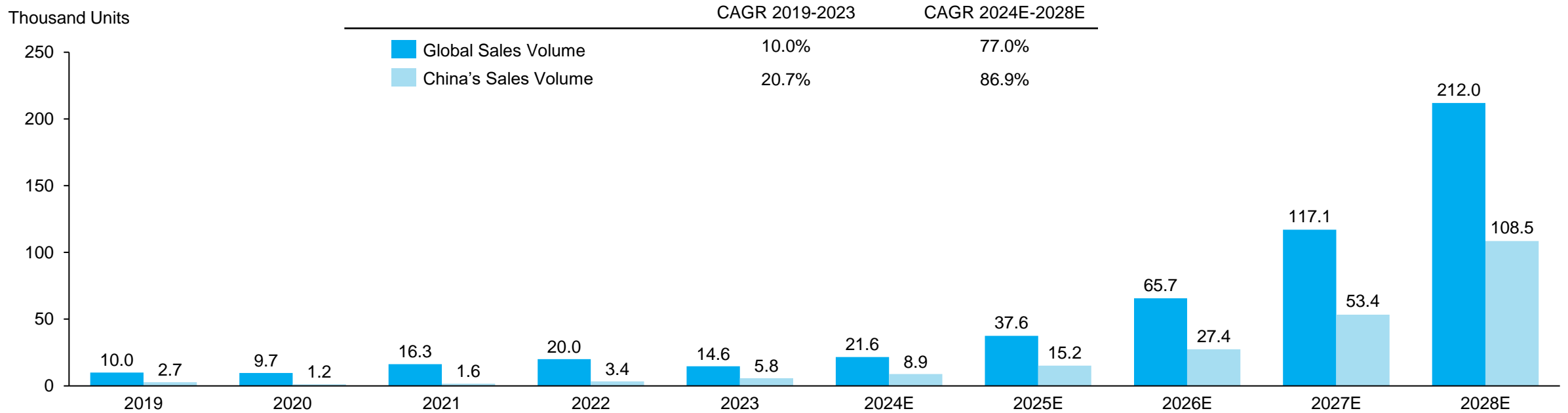
## Overview of Hydrogen Fuel Cell Vehicle

- Hydrogen fuel cell vehicles (HFCVs) hold substantial promise as one of the main directions in the transition towards low-carbon energy in the automotive sector, offering several compelling advantages over traditional internal combustion engine vehicles and electric vehicles. One of the most significant benefits is the refueling time. HFCVs can be refueled in several minutes, akin to traditional internal combustion engine vehicles, offering convenience and efficiency for drivers. This compares favorably to battery electric vehicles (BEVs), which, even with fast charging technology, require significantly more time to recharge. In addition, HFCVs boast relatively long mileage, which not only addresses range anxiety issues that are still prevalent among BEV consumers, but also makes it an excellent carrier for energy storage and transportation over long distances. Moreover, there is no carbon emission or pollution when operating HFCVs. This is a crucial factor as the world increasingly seeks sustainable and environmentally friendly transportation solutions to combat climate change. Meanwhile, the development of HFCVs also encourages the growth of renewable energy sectors, as hydrogen can be produced through water electrolysis powered by renewable energy. This symbiotic relationship could facilitate a broader integration of renewable energy into the transportation sector, enhancing energy security and reducing dependency on fossil fuels. Finally, the continuous advancements in hydrogen infrastructure, such as the increasing number of hydrogen refueling stations and improvements in the logistics of hydrogen transportation and storage, continue to support the promotion of HFCVs. As a result of combined advantages above, HFCVs are likely to become one of the main directions for the development of low-carbon energy in vehicles in the future.
- The rise in popularity of BEVs has led to increased competition in the automotive industry in China, where both BEVs and HFCVs are gaining traction. This competition from BEVs encourages hydrogen core equipment manufacturers to focus on technological advancements, such as enhancing the performance and cost-effectiveness of hydrogen-related technologies. This drive for innovation holds the potential to yield breakthroughs across various aspects of the production, storage, transportation and use of hydrogen, thereby benefiting the entire hydrogen ecosystem. In addition, HFCV manufacturers may differentiate themselves in the rapidly evolving new energy vehicle market by emphasizing the inherent advantages of HFCVs over BEVs, such as longer mileage, quicker refueling times and suitability for heavy-duty applications. This differentiation strategy is pivotal for capturing niche markets and sustaining demand for both HFCV manufacturers and relevant hydrogen core equipment manufacturers. Furthermore, compared to the well-established BEV market, China's HFCVs industry is still in the initial stage of commercialization. In the future, it is expected that the government will take proactive measures to promote the growth of the HFCV market, recognizing its potential to contribute to environmental sustainability and energy diversification. Overall, as China seeks to transition towards a low-carbon economy, the government's proactive support and strategic policy interventions are expected to play a pivotal role in propelling the commercial development of the HFCV market and catalyzing the growth of all the stakeholders in the hydrogen energy industry, including hydrogen core equipment manufacturers.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis of HFCVs

Sales Volume of HFCV (Global and China), 2019-2028E



- Commercial vehicles such as buses, logistic vehicles and trucks are major types of hydrogen fuel cell vehicles in China while in the international market, passenger vehicles such as sedans and sport utility vehicles (“SUV”s) are representative application of hydrogen fuel cell vehicles. Global hydrogen fuel cell vehicle industry has experienced a relatively stable growth in sales volume from 10.0 thousand units in 2019 to 14.6 thousand units in 2023, with a CAGR of 10.0%, and is expected to reach 212.0 thousand units in 2028. China’s hydrogen fuel cell vehicle industry was in its early start-up phase from 2019 to 2023, with sales volume rising from 2.7 thousand units to 5.8 thousand units, at a CAGR of 20.7%. According to the development goals in the “Mid-to-Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)” (《氢能產業發展中長期規劃(2021-2035年)》), the total number of hydrogen fuel cell vehicles in China will reach approximately 50,000 units in 2025. Driven by strong policy support, continuous breakthroughs in core technologies and improved equipment such as vehicle-mounted high-pressure hydrogen storage cylinder, the sales volume of hydrogen fuel cell vehicles in China will enter a stage of rapid growth. China is expected to become the largest market in global hydrogen fuel cell vehicle industry and witness a surge in its sales volume of hydrogen fuel cell vehicles, from approximately 8.9 thousand units in 2024 to 108.5 thousand units in 2028, with a CAGR of approximately 86.9%.



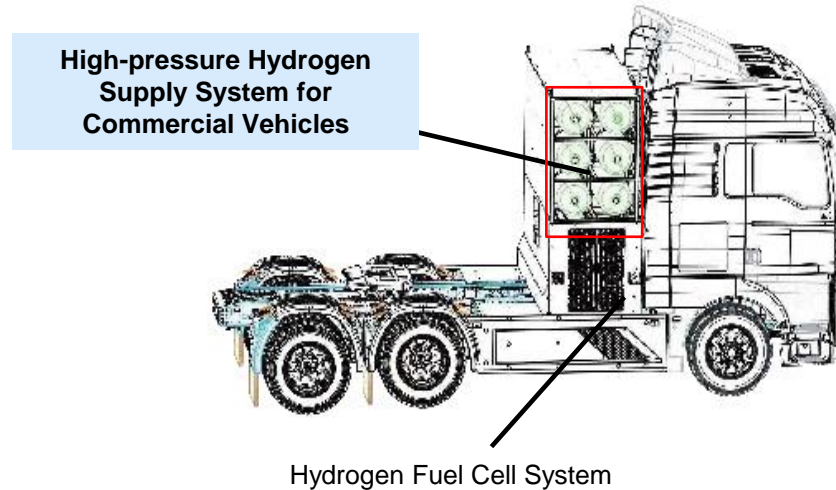
# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Overview of Vehicle-mounted High-pressure Hydrogen Supply System

### Definition of Vehicle-mounted high-pressure Hydrogen Supply System

- Vehicle-mounted high-pressure hydrogen supply system is the mainstream type of hydrogen supply system for the hydrogen fuel cell vehicles in the current stage and serves as the energy storage unit for the vehicle, which is responsible for storing and supplying hydrogen to the hydrogen fuel cell stack.
- The vehicle-mounted high-pressure hydrogen supply system is primarily composed of high-pressure hydrogen storage cylinders, pipelines and valves parts, pressure/temperature sensors, control systems and other components.

### Structure of Hydrogen Fuel Cell Vehicle



# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Comparison of the Major Types of High-pressure Hydrogen Storage Cylinders in Hydrogen Supply Systems

### Comparison of High-pressure Hydrogen Storage Cylinders

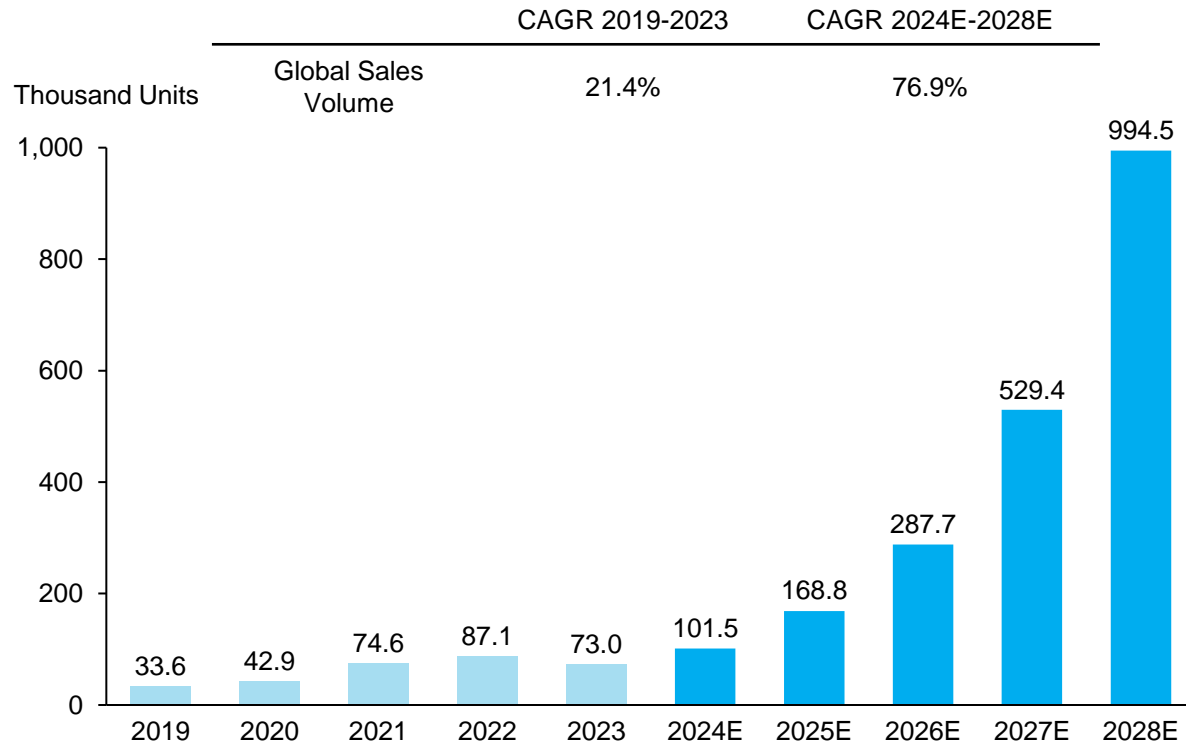
	Type-I Cylinder	Type-II Cylinder	Type-III Cylinder	Type-IV Cylinder
<b>Material</b>	Pure steel metal	Steel-lined fiber wound	Aluminum-lined carbon fiber wound	Polymeric-lined carbon fiber wound
<b>Maximum Pressure (Mpa)</b>	17.5-20	26-30	30-70	30-70
<b>Weight-to-volume Ratio (Kg/L)</b>	0.9-1.3	0.6-1.0	0.35-1.0	0.3-0.8
<b>Cost</b>	Low	Medium	High	
<b>Lifespan</b>	15 years		15-20 years	
<b>Automotive Use</b>	Not applicable		Applicable	
<b>Major Applications</b>	Stationary hydrogen storage scenarios such as hydrogen refueling station		Hydrogen fuel cell vehicle	

- For high-pressure gaseous hydrogen storage, hydrogen storage cylinders can be divided into four types according to their materials, namely 1) pure steel metal cylinders (Type-I), 2) steel-lined fiber wound cylinders (Type-II), 3) aluminum-lined carbon fiber wound cylinders (Type-III) and 4) plastic-liner carbon fiber wound cylinders (Type-IV). Vehicle-mounted high-pressure hydrogen storage cylinder is currently the most widely used gaseous hydrogen storage method and is one of the core components of the vehicle-mounted high-pressure hydrogen supply system.
- Type-I hydrogen storage cylinders are made of metals solely, such as steel. Type-II hydrogen storage cylinders have carbon fiber or glass fiber wound around the body. Type-I and Type-II hydrogen storage cylinders are easy to manufacture with relatively low costs. However, they are relatively heavy, which are only used for stationary hydrogen storage scenarios such as hydrogen refueling stations due to low hydrogen storage density and hydrogen embrittlement issues.
- Type-III and Type-IV hydrogen storage cylinders are constructed with a full winding of carbon fiber, making them ideal for vehicle applications due to their significant weight reduction compared to Type-I and Type-II cylinders. Despite the considerable weight savings, ensuring optimal performance necessitates higher manufacturing costs for Type-III and Type-IV cylinders compared to their counterparts. Currently, China's hydrogen fuel cell vehicles primarily use Type-III cylinders, while Type-IV cylinders have been widely used in the overseas markets. The technology for Type-IV cylinders in China is still in its early stages and has not yet reached commercial-scale mass production. As a result, the price of Type-IV cylinders with similar specifications is higher than that of Type-III cylinders in China.

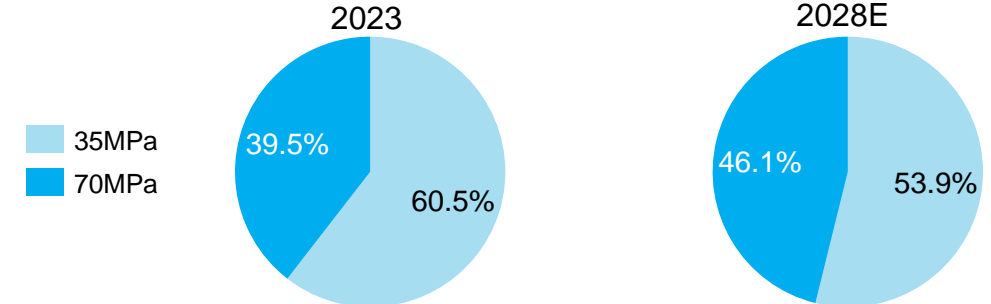
# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

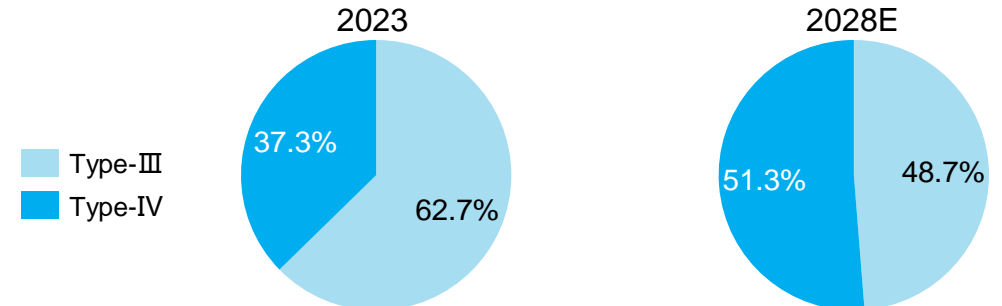
Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders (Global), 2019-2028E



Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Pressure Specification (Global), 2023 and 2028E



Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Type of Cylinders (Global), 2023 and 2028E

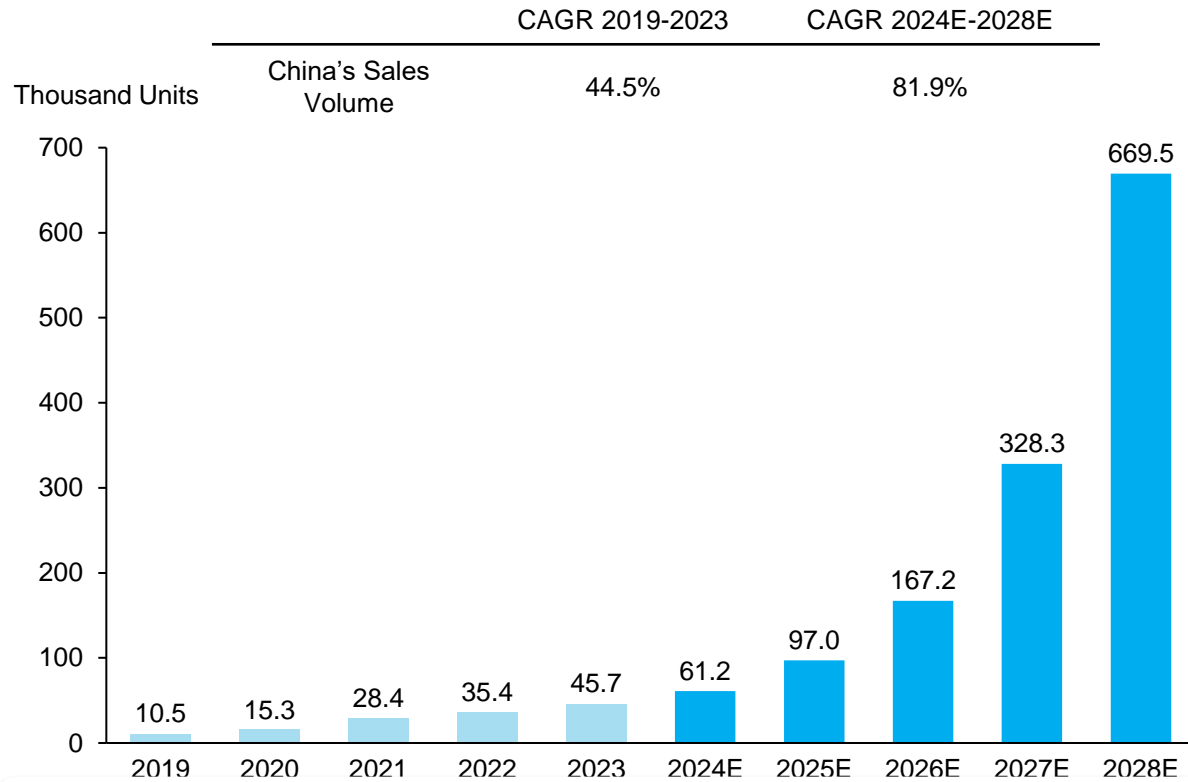


- From 2019 to 2023, the global sales volume of vehicle-mounted high-pressure hydrogen storage cylinders has increased from 33.6 thousand units to approximately 73.0 thousand units with a CAGR of 21.4%. China's HFCV market is dominated by commercial vehicles equipped with 35MPa Type-III high-pressure hydrogen storage cylinders, and this feature is expected to continue in the short term. Overseas HFCV market is dominated by passenger HFCVs using hydrogen storage cylinders with higher pressure level to ensure the compact size and driving range. 70MPa Type-IV hydrogen storage cylinder has become the mainstream type of cylinders in the overseas market. Due to the increasing sales volume of commercial HFCVs in China, 35MPa vehicle-mounted hydrogen storage cylinders has become the mainstream type in the world with a global market share of 60.5% in 2023 and the global proportion of Type-III hydrogen storage cylinders in terms sales volume was 62.7% in 2023. Looking forward, with the further growth in HFCV sales volume in China and the application of Type-IV hydrogen storage cylinders in China, the proportion of global 35MPa high-pressure hydrogen storage cylinders and Type-III high-pressure hydrogen storage cylinders is expected to reach 53.9% and 48.7% in 2028, respectively.

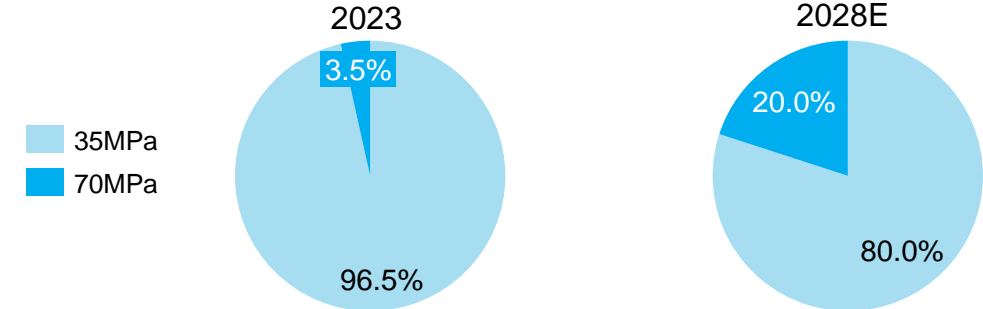
# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

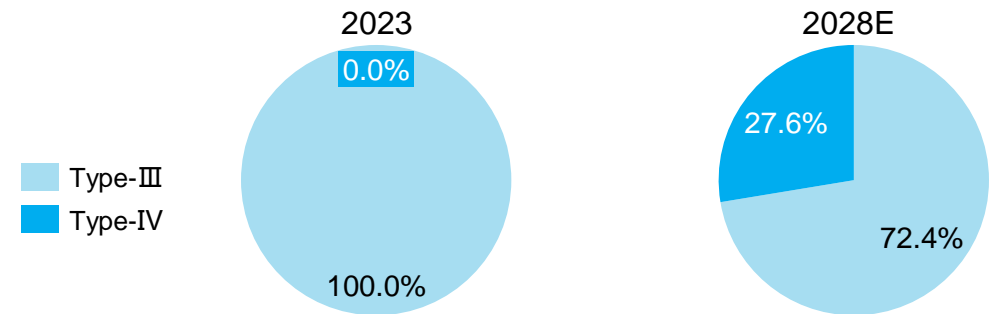
Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders (China), 2019-2028E



Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Pressure Specification (China), 2023 and 2028E



Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Type of Cylinders (China), 2023 and 2028E



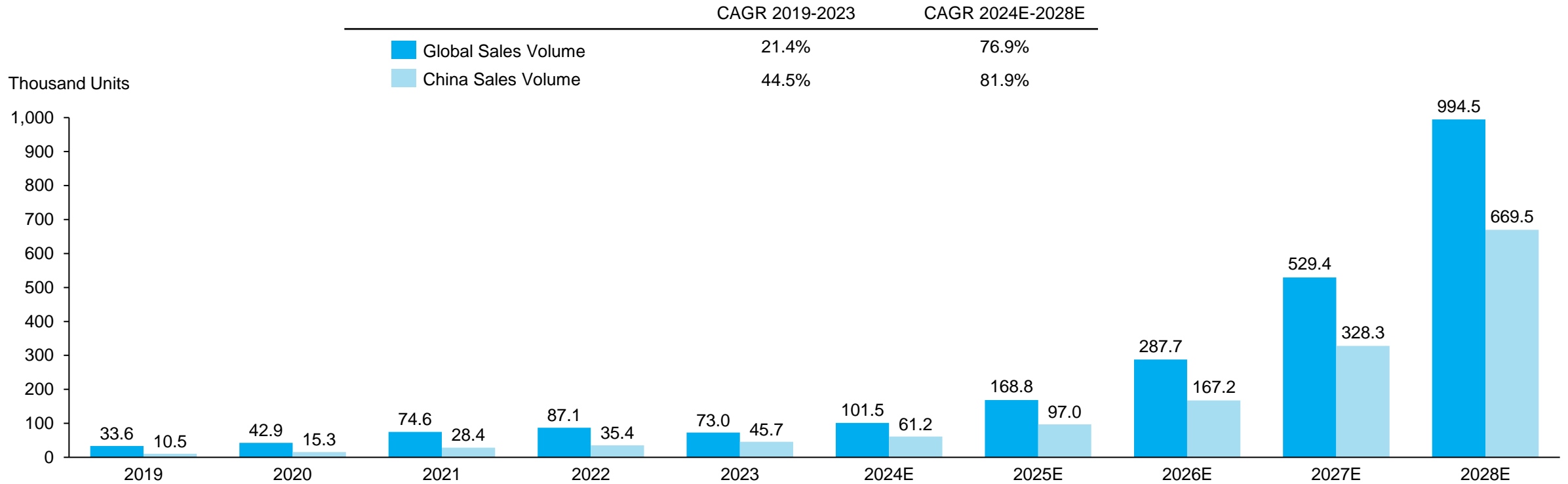
- From 2019 to 2023, the sales volume of vehicle-mounted high-pressure hydrogen storage cylinders in China grew from 10.5 thousand units to approximately 45.7 thousand units with a CAGR of 44.5%. As commercial HFCVs are the major types of HFCVs in China and have lower requirements on pressure level than passenger HFCVs, 35MPa vehicle-mounted hydrogen storage cylinders took up 96.5% of total market in China in 2023. So far, due to regulatory restrictions, Type-III hydrogen storage cylinders are the mainstream specifications for vehicle-mounted high-pressure hydrogen storage cylinders in China. As the national standard "Automotive Compressed Hydrogen Plastic Liner Carbon Fiber Fully Wound Cylinder" (《车用压缩氢气塑料内胆碳纤维全缠绕气瓶》) be officially implemented on June 1, 2024, Type-IV hydrogen storage cylinders will begin the initial commercial application in China. With the advancement of related technologies and the construction of large-scale production capabilities, Type-IV hydrogen storage cylinders will be gradually promoted in China in the future. In addition, application of 70MPa hydrogen storage cylinders will become another focus of the industry to extend driving range of HFCVs as well as support the promotion of passenger HFCVs in China. It is foreseeable that the sales volume of vehicle-mounted high-pressure hydrogen storage cylinders in China will reach 669.5 thousand units in 2028, among with 70MPa and Type-IV cylinders taking up market shares of 20.0% and 27.6%, respectively.

Note: The sales volume of vehicle-mounted high-pressure hydrogen storage cylinders include: 1) vehicle-mounted high-pressure hydrogen storage cylinders sold as individual products and 2) vehicle-mounted high-pressure hydrogen storage cylinders sold as components of the vehicle-mounted high-pressure hydrogen storage systems.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

Sales Volume of Vehicle-mounted High-pressure Hydrogen Storage Cylinders (Global and China), 2019-2028E

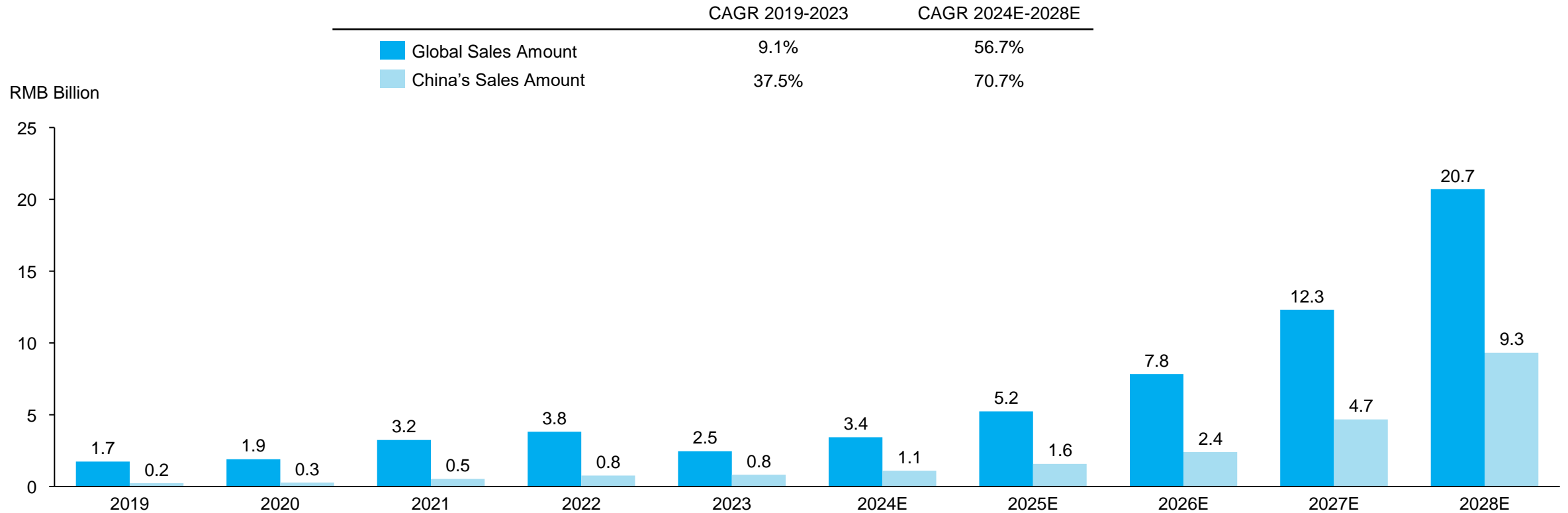


Note: The sales volume of vehicle-mounted high-pressure hydrogen storage cylinders include: 1) vehicle-mounted high-pressure hydrogen storage cylinders sold as individual products and 2) vehicle-mounted high-pressure hydrogen storage cylinders sold as components of the vehicle-mounted high-pressure hydrogen storage systems.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

Sales Amount of Vehicle-mounted High-pressure Hydrogen Storage Cylinders (Global and China), 2019-2028E

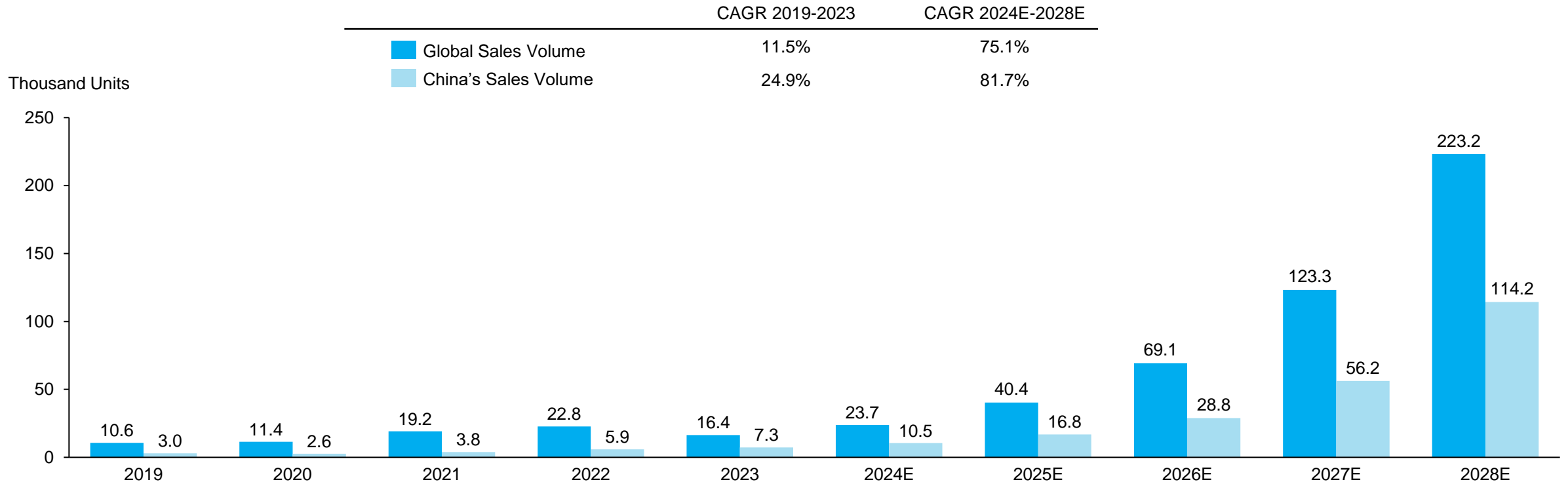


Benefiting from the rapid growth of sales of HFCVs in both global and China's market, the market size of vehicle-mounted high-pressure hydrogen storage cylinders in both globe and China by sales amount increased to approximately RMB2.5 billion and RMB0.8 billion in 2023, respectively. In the future, with the sustainable growth in HFCVs and further maturation of relevant technologies and production process, the corresponding market size of vehicle-mounted high-pressure hydrogen storage cylinders in both globe and China by sales amount is expected to reach approximately RMB20.7 billion and RMB9.3 billion in 2028, representing CAGRs of 56.7% and 70.7% from 2024, respectively.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

Sales Volume of Vehicle-mounted High-pressure Hydrogen Supply Systems (Global and China), 2019-2028E



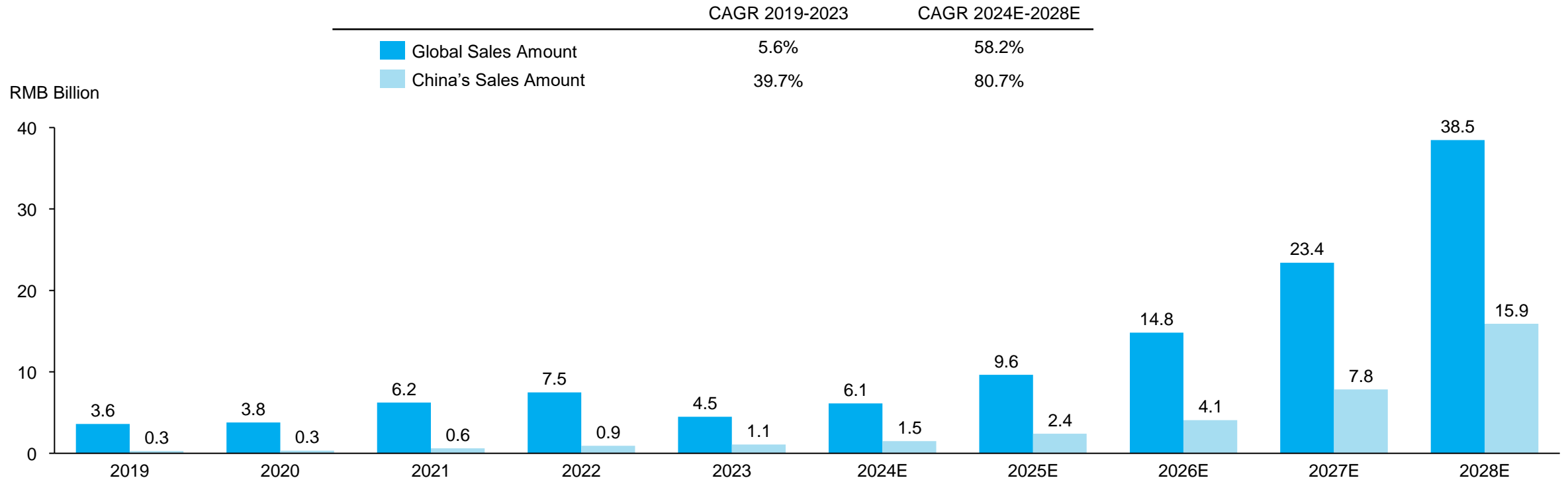
Every unit of HFCV typically carries one high-pressure hydrogen supply system as energy unit. As HFCV has gained considerable attention from governments worldwide as a less emission transportation solution, the technology research, production and application of vehicle-mounted high-pressure hydrogen supply systems in the global and China's markets have also continued to develop along with HFCV industry. The sales volume of global and China's vehicle-mounted high-pressure hydrogen supply systems reached approximately 16.4 and 7.3 thousand units in 2023, representing CAGRs of 11.5% and 24.9% from 2019, respectively. Moving forward, the continuous technological innovation and large-scale promotion of HFCVs will poise for growth in demand for vehicle-mounted high-pressure hydrogen supply systems. The sales volume of global and China's vehicle-mounted high-pressure hydrogen supply systems is expected to further increase to 223.2 and 114.2 thousand units in 2028, representing CAGRs of 75.1% and 81.7% from 2024, respectively.



# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Size Analysis

Sales Amount of Vehicle-mounted High-pressure Hydrogen Supply Systems (Global and China), 2019-2028E



- With the strong support from the government, the continuous breakthrough of core technologies and improvement of relevant infrastructure construction, the sales amount of global and China's vehicle-mounted high-pressure hydrogen supply systems increased from RMB3.6 billion and RMB0.3 billion in 2019 to approximately RMB4.5 billion and RMB1.1 billion in 2023, representing CAGRs of 5.6% and 39.7%, respectively. Moving forward, due to technological breakthrough and maturity of supply chain, both passenger and commercial HFCVs will accelerate entry into mass application stage, further promoting the demand and market size of overall vehicle-mounted high-pressure hydrogen supply systems. It is foreseeable that, by 2028, the market size of vehicle-mounted high-pressure hydrogen supply systems will reach RMB38.5 billion and RMB15.9 billion in both global and China's market, representing CAGRs of 58.2% and 80.7%, respectively.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Market Drivers and Developing Trends for Vehicle-mounted High-pressure Hydrogen Supply Systems

**Regulatory policies promote hydrogen as key strategy to combat climate change**

As an important measure to tackle climate change and accelerate energy transformation, increasing number of economies attach great importance to the development of the hydrogen energy industry and regard it as a part of the energy development strategy. Hydrogen energy has become an important solution for accelerating the transformation and upgrading of energy structure as well as cultivating new economic growth drivers. Favorable policies globally will further promote the application of hydrogen fuel cell vehicles and development of the relevant core components and equipment, thus driving the growth of vehicle-mounted high-pressure hydrogen supply systems industry and vehicle-mounted high-pressure hydrogen storage cylinders industry.

**Continuous development of hydrogen fuel cell vehicle and relevant infrastructure systems**

Hydrogen fuel cell vehicles reduce the environmental impact of traditional internal combustion engine vehicles, while tackling the problems of mileage anxiety and long charging time of electric vehicles. Hydrogen fuel cell vehicles are likely to become one of the main directions for the development of low-carbon energy in vehicles. Furthermore, with the continuous construction of infrastructure system featuring with the production, storage, transportation and refueling of hydrogen energy, it is expected that the demand for Hydrogen fuel cell vehicles will further increase, thus promoting the development of vehicle-mounted high-pressure hydrogen supply systems industry and vehicle-mounted high-pressure hydrogen storage cylinders industry in both global and China's markets.

**Technological transformation in hydrogen storage cylinders**

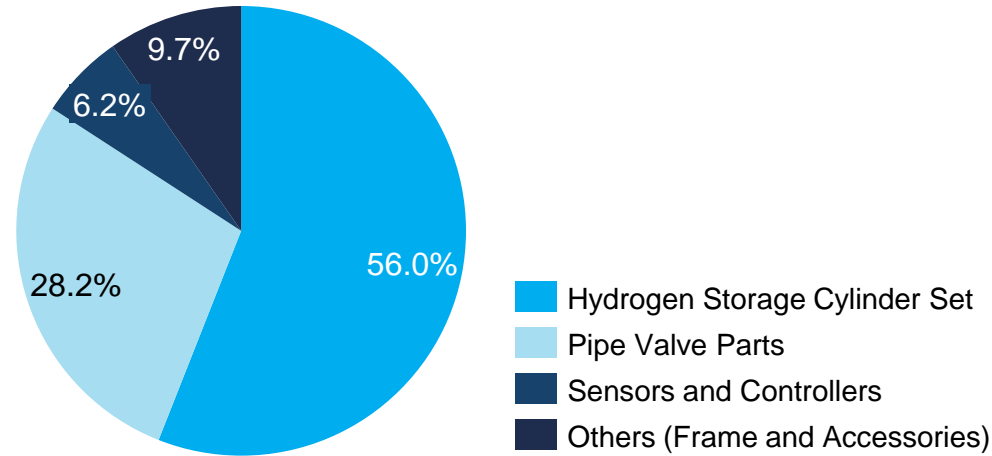
Currently, considering factors such as cost and operational stability, the 35MPa Type-III cylinder serves as the predominant vehicle-mounted hydrogen storage solution in China in the short-term. Looking forward, considering (i) the approval of Type-IV cylinder production in China; (ii) the advancement of 70MPa hydrogen storage technology for hydrogen fuel cell vehicles and refueling infrastructure; and (iii) the rising demand for longer range and higher capacity vehicles, the specifications for vehicle-mounted high-pressure hydrogen storage cylinders in China will gradually expand from 35MPa Type-III cylinders to 70MPa Type-III and Type-IV cylinders.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

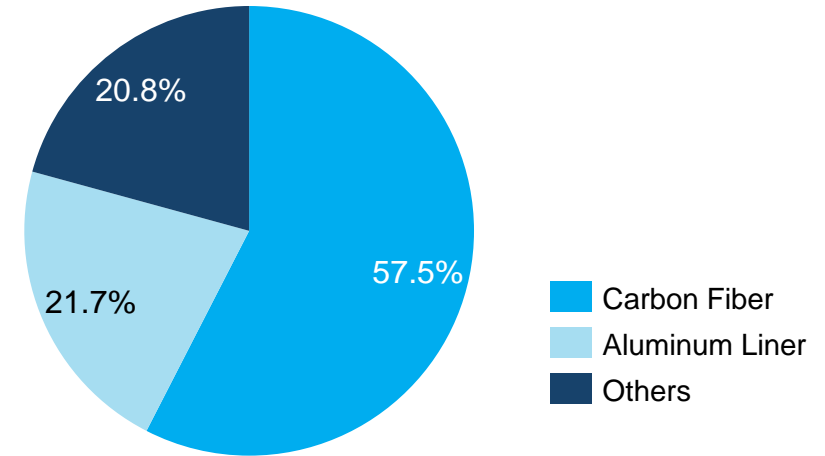
## Cost Structure Analysis of a Vehicle-mounted High-pressure Hydrogen Supply System

### Cost Structure Analysis of Vehicle-mounted High-pressure Hydrogen Supply Systems (China), 2023

Cost Structure of a Vehicle-mounted Hydrogen Supply System with the a Set of six 140L-35MPa Type-III Cylinders



Cost Structure of a Vehicle-mounted 140L-35MPa Type-III Cylinder



- The raw material cost structure of a vehicle-mounted high-pressure hydrogen supply system cylinder mainly include hydrogen storage cylinder set, pipe valve parts, sensors and controllers, and others (frame and accessories), among which the set of hydrogen storage cylinders accounted for the largest proportion of the total cost of the system, followed by pipe valve parts, sensors and controllers, and others (frame and accessories).
- For a single vehicle-mounted hydrogen storage cylinder, the raw material cost structure of a high-pressure hydrogen storage cylinder mainly include carbon fiber, liner part and others, among which the carbon fiber accounted for over 50% of the total raw material costs of a cylinder.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

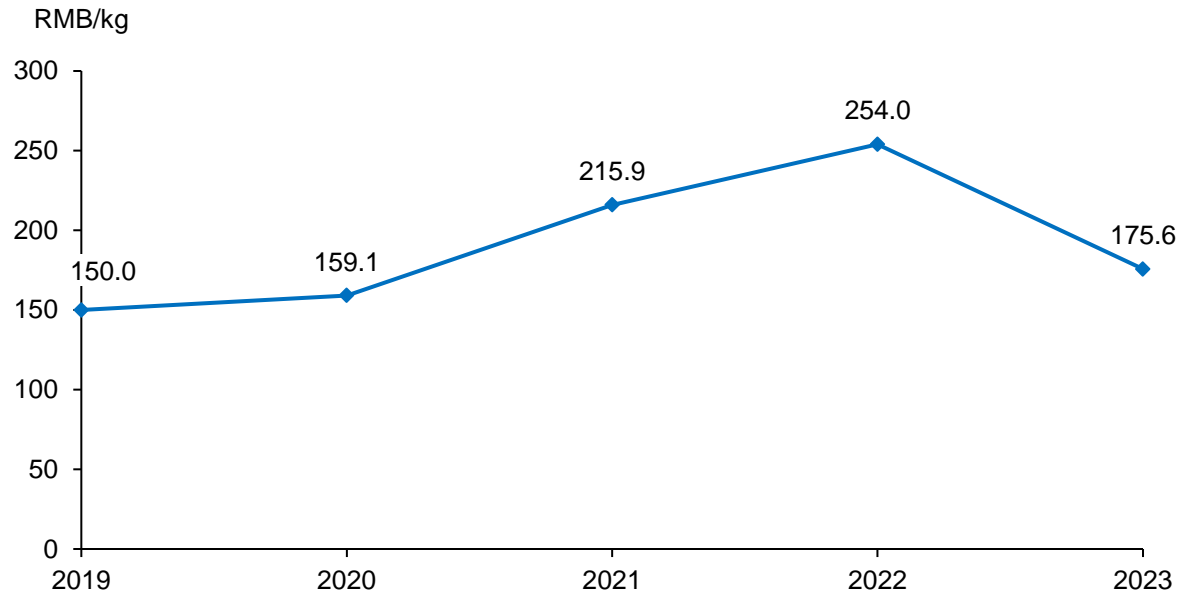
## Price Analysis of Vehicle-mounted High-pressure Hydrogen Supply Systems in China

- In order to meet the demands of downstream hydrogen fuel cell vehicle manufacturers for longer driving range and larger loading capacity, vehicle-mounted high-pressure hydrogen supply systems are gradually developing towards “large-volume and multi-cylinder sets” (大容量、多瓶组). As a result, the price of China’s vehicle-mounted high-pressure hydrogen supply system has shown an overall upward trend in the past few years. For a single vehicle-mounted high-pressure hydrogen storage cylinder, with the increase in the domestication of raw materials, the price of the vehicle-mounted high-pressure hydrogen storage cylinder in China of the same specification has experienced a modest decline. Meanwhile, the emergence of some large-volume storage cylinders and heightened demand for 70MPa hydrogen storage cylinders spurred by downstream hydrogen fuel cell passenger vehicles has had a certain upward impact on the overall average price of vehicle-mounted high-pressure hydrogen storage cylinders in China. Looking forward, as hydrogen fuel cell vehicles are increasingly promoted and related technologies continue to advance, it is anticipated that the prices of vehicle-mounted high-pressure hydrogen supply systems and high-pressure hydrogen storage cylinders with the same specification in China will gradually decrease in the future.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

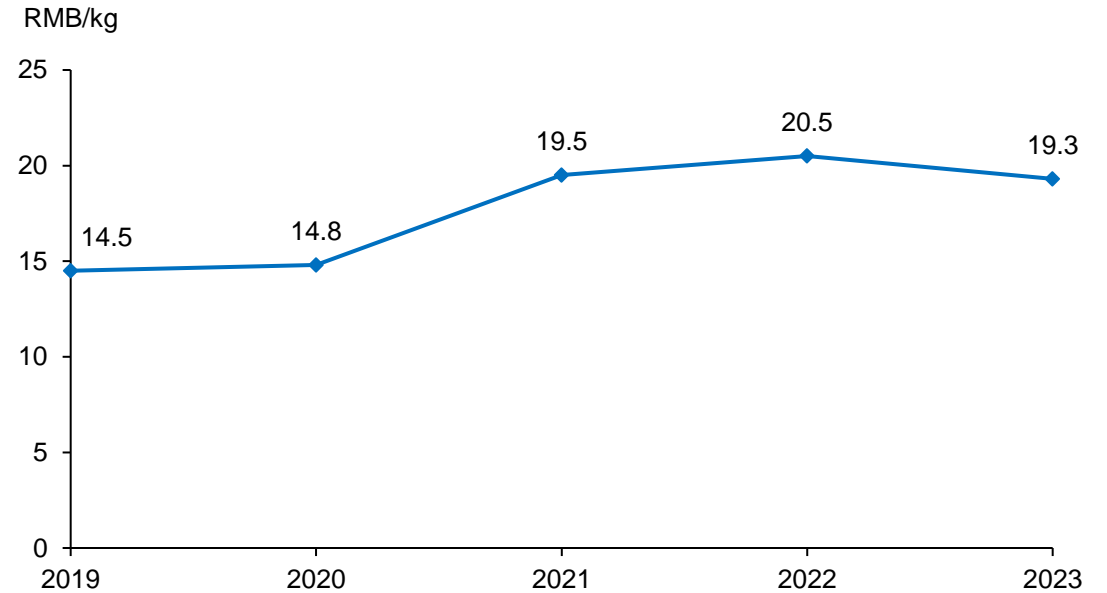
## Price Analysis of Raw Materials and Products for Vehicle-mounted High-pressure Hydrogen Supply Systems

### Prices of Carbon Fiber (China), 2019-2023



- The raw material cost structure of a vehicle-mounted high-pressure hydrogen supply system mainly include hydrogen storage cylinders, pipe valve parts, sensors and controllers and others, among which the hydrogen storage cylinders accounted for the largest proportion of the system's total cost. For a single vehicle-mounted hydrogen storage cylinder, the raw material cost structure mainly includes carbon fiber and aluminum liner and others, among which the carbon fiber accounted for over 50% of the total raw material costs of a hydrogen storage cylinder. In particular, carbon fiber serves as a reinforcing material in hydrogen storage cylinders to enhance the load-bearing capacity and durability of the container. As an advanced material for hydrogen storage cylinders, carbon fiber encountered supply constraints due to limited domestic production and foreign export controls over the past few years, resulting in an increase of price in 2021 and 2022. With the domestication of core technologies and increase in production capacity in China, the price of carbon fiber has gradually decreased and reached RMB175.6/kg in 2023.

### Prices of Aluminum Rod (China), 2019-2023



- Aluminum rods is of paramount importance in hydrogen storage cylinders in contribution of efficiency and reliability. The lightweight nature of aluminum makes the cylinder structure durable and lightweight in applications, especially HFCVs. Additionally, aluminum is highly corrosion-resistant, safeguarding the cylinder against potential degradation caused by hydrogen exposure. It also exhibits high thermal conductivity, helping to effectively manage the heat generated during hydrogen storage. With the wider applications and thriving downstream demands, the price of aluminum rods in China gradually increased from RMB14.5/kg in 2019 to RMB20.5/kg in 2022, and then recovered to RMB19.3/kg in 2023.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Barriers to Enter into the Vehicle-mounted High-pressure Hydrogen Supply System Industry

1

### Technological Capabilities Barrier

- The vehicle-mounted high-pressure hydrogen supply systems industry is a technology-driven industry. Some key technologies such as the relevant production technology of the core components of Type-IV hydrogen storage cylinders are still monopolized by overseas suppliers. Meanwhile, the winding process of hydrogen storage cylinders is relatively complicated, and vehicle-mounted high-pressure hydrogen supply system itself has a high technological threshold, requiring continuous R&D inputs. In addition, high-pressure hydrogen storage cylinders are special equipment and must obtain the B3 grade pressure vessel special equipment manufacturing license from Chinese competent authorities before they can be produced. This also places higher requirements on the manufacturer's technical capabilities, production processes and quality consistency.

2

### Production Capabilities Barrier

- Control of supply chain and capital investment are crucial to strong and stable production capacity for companies in vehicle-mounted high-pressure hydrogen supply systems industry. Establishing a robust supply chain system contributes to reducing production risks and enhance production stability. In addition, companies that can secure sufficient financial investment in design, development and construction of production facilities are more likely to establish stable production capacity and strengthen its competitive position.

3

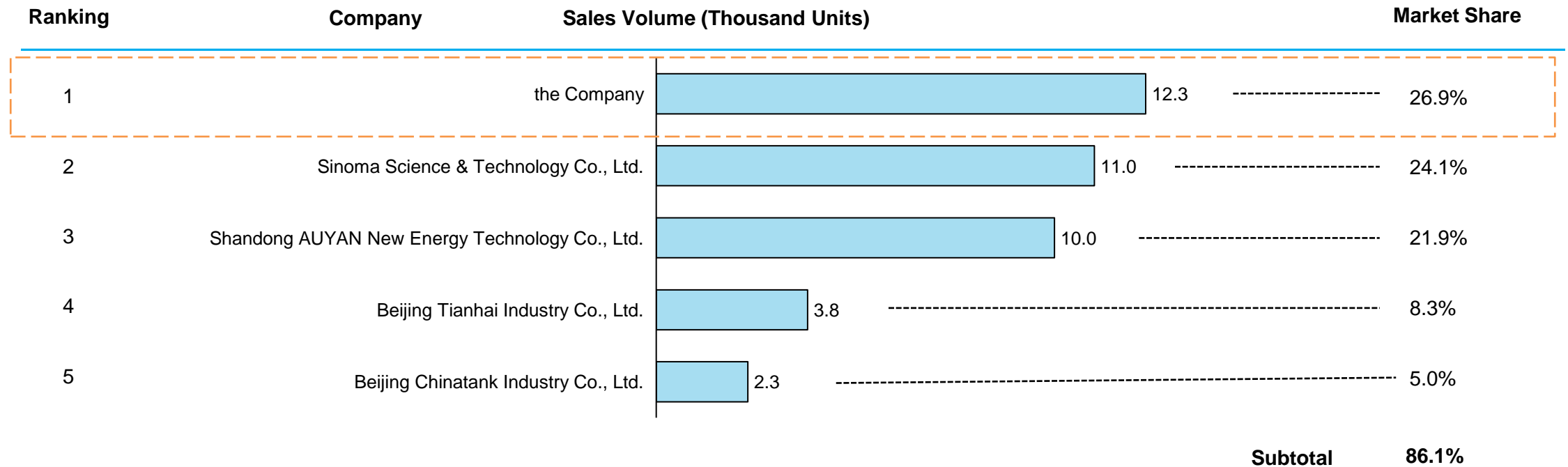
### Brand and Customer Recognition Barrier

- Leading vehicle-mounted high-pressure hydrogen supply system manufacturers actively establish close cooperative relationships with different partners to ensure stable product sales and improve brand image. These companies are able to continuously expand the scale and scope of cooperation based on the reputation they have accumulated in the industry. A broad and diverse customer base also provides vehicle-mounted high-pressure hydrogen supply system manufacturers with further growth opportunities by tapping into new products or new application scenarios.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Competitive Landscape of Vehicle-mounted High-pressure Hydrogen Storage Cylinders Industry in China

Top Five Companies of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Sales Volume (China), 2023



- Both vehicle-mounted high-pressure hydrogen storage cylinders industry and vehicle-mounted high-pressure hydrogen supply systems industry are relatively concentrated. The top five players had an aggregate of 86.1% of the market share of vehicle-mounted high-pressure hydrogen storage cylinders industry in terms of sales volume in 2023. We ranked first among all providers of vehicle-mounted high-pressure hydrogen storage cylinders in China, with a market share of 26.9% in China's vehicle-mounted high-pressure hydrogen storage cylinders industry.

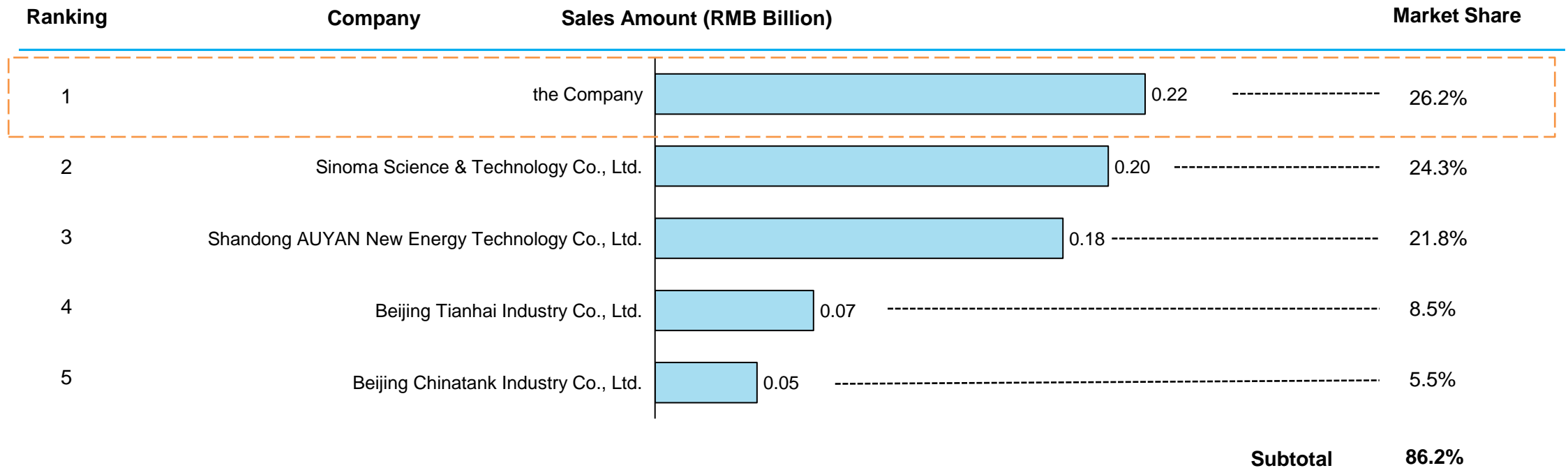
Note: The sales volume of vehicle-mounted high-pressure hydrogen storage cylinders include: 1) vehicle-mounted high-pressure hydrogen storage cylinders sold as individual products and 2) vehicle-mounted high-pressure hydrogen storage cylinders sold as components of the vehicle-mounted high-pressure hydrogen storage systems.



# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Competitive Landscape of Vehicle-mounted High-pressure Hydrogen Storage Cylinders Industry in China

Top Five Companies of Vehicle-mounted High-pressure Hydrogen Storage Cylinders by Sales Amount (China), 2023



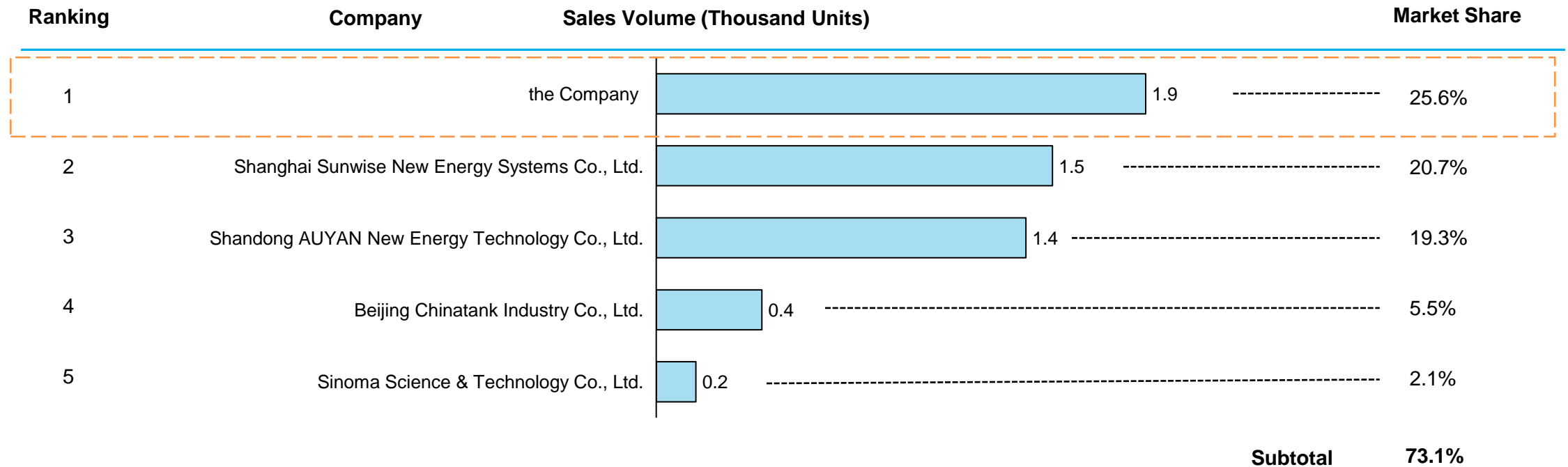
- Both vehicle-mounted high-pressure hydrogen storage cylinders industry and vehicle-mounted high-pressure hydrogen supply systems industry are relatively concentrated. The top five players had an aggregate of 86.2% of the market share of vehicle-mounted high-pressure hydrogen storage cylinders industry in terms of sales amount in 2023. We ranked first among all providers of vehicle-mounted high-pressure hydrogen storage cylinders in China, with a market share of 26.2% in China's vehicle-mounted high-pressure hydrogen storage cylinders industry.

Note: The sales amount of vehicle-mounted high-pressure hydrogen storage cylinders include: 1) vehicle-mounted high-pressure hydrogen storage cylinders sold as individual products and 2) vehicle-mounted high-pressure hydrogen storage cylinders sold as components of the vehicle-mounted high-pressure hydrogen storage systems.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Competitive Landscape of Vehicle-mounted High-pressure Hydrogen Supply Systems Industry in China

Top Five Companies of Vehicle-mounted High-pressure Hydrogen Supply Systems by Sales Volume (China), 2023

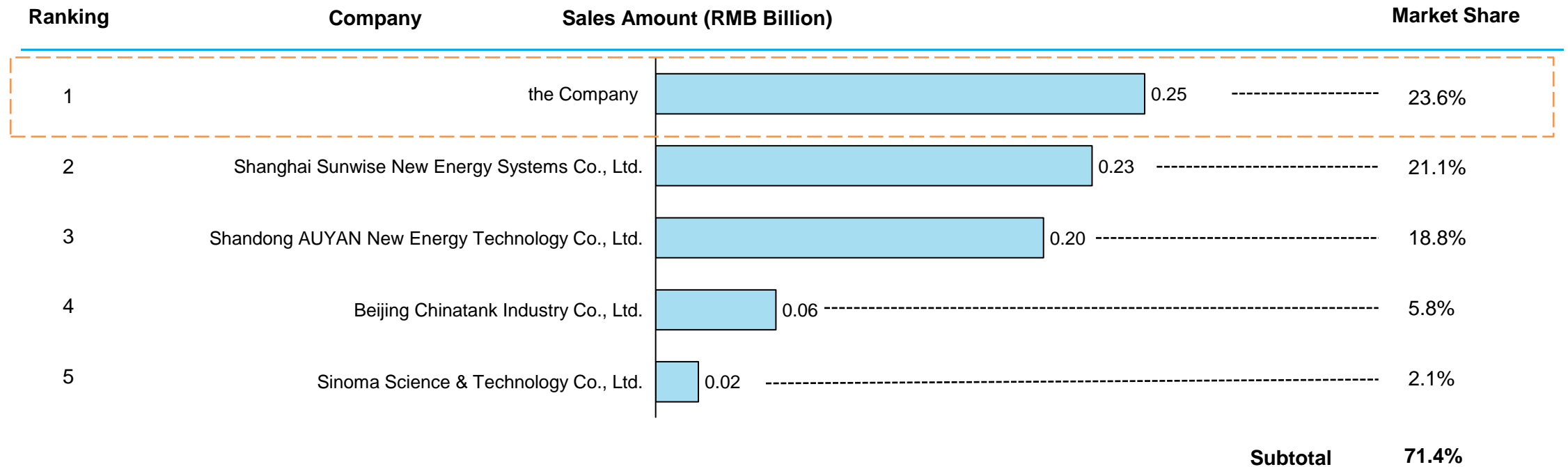


- In addition, the top five players had an aggregate of 73.1% of the market share of vehicle-mounted high-pressure hydrogen supply systems industry in terms of sales volume in 2023. We ranked first among all providers of vehicle-mounted high-pressure hydrogen supply systems in China, with a market share of 25.6% in China's vehicle-mounted high-pressure hydrogen supply systems industry.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Competitive Landscape of Vehicle-mounted High-pressure Hydrogen Supply Systems Industry in China

Top Five Companies of Vehicle-mounted High-pressure Hydrogen Supply Systems by Sales Amount (China), 2023



- In addition, the top five players had an aggregate of 71.4% of the market share of vehicle-mounted high-pressure hydrogen supply systems industry in terms of sales amount in 2023. We ranked first among all providers of vehicle-mounted high-pressure hydrogen supply systems in China, with a market share of 23.6% in China's vehicle-mounted high-pressure hydrogen supply systems industry.

# Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry

## Company Profile of Major Players

Company Name	Year of Establishment /Headquarter	Listed/Unlisted	Business Introduction
Sinoma Science & Technology Co., Ltd. 中材科技股份有限公司	2001, Beijing, China	Listed (SZ.002080)	<ul style="list-style-type: none"> <li>The company's business covers non-metallic mineral materials, glass fiber, fiber composite material. In the field of high-pressure gas cylinders, the company is mainly engaged in the production and sale of vehicle control CNG cylinders, automotive steel deep drawing CNG cylinders, tube bundles and hydrogen cylinders, etc. It has two professional production base of cylinders (Suzhou base, Chengdu base), with an annual output of 550,000 cylinders of various types of production capacity.</li> </ul>
Shandong AUYAN New Energy Technology Co., Ltd. 山东奥扬新能源科技股份有限公司	2011, Weifang, Shandong Province, China	Unlisted	<ul style="list-style-type: none"> <li>The company focuses on the field of new energy equipment manufacturing, including the two main energy lines of natural gas and hydrogen. It is mainly engaged in automobile gas supply equipment systems, energy storage and transportation equipment systems, and hydrogen production and refueling integrated equipment systems.</li> </ul>
Beijing Tianhai Industry Co., Ltd. 北京天海工业有限公司	1992, Beijing, China	Unlisted	<ul style="list-style-type: none"> <li>The company produces various specifications of steel seamless gas cylinders, wound gas cylinders, accumulator shells, asbestos-free filler acetylene bottles, welded insulated gas cylinders, carbon fiber fully wound composite gas cylinders (including vehicle-mounted gas cylinders), low-temperature tank containers and products for gas filling stations.</li> </ul>
Beijing Chinatank Industry Co., Ltd. 北京科泰克科技有限责任公司	2003, Beijing, China	Unlisted	<ul style="list-style-type: none"> <li>The company is a high-tech enterprise specializing in the production of high-pressure containers, and has long been engaged in the design, production and sales of aluminium alloy liners, breathing cylinders, composite cylinders for vehicles, high-pressure and ultra-high-pressure containers.</li> </ul>
Shanghai Sunwise New Energy Systems Co., Ltd. 上海舜华新能源系统有限公司	2004, Shanghai, China	Unlisted	<ul style="list-style-type: none"> <li>The company mainly provides vehicle-mounted hydrogen supply systems, hydrogen refueling station equipment, and engineering and technical services. It has mastered the core technology of high-pressure hydrogen processing and is exploring the field of hydrogen production (hydrogen production EPC business from wind power and photovoltaic waste electricity).</li> </ul>

# Agenda

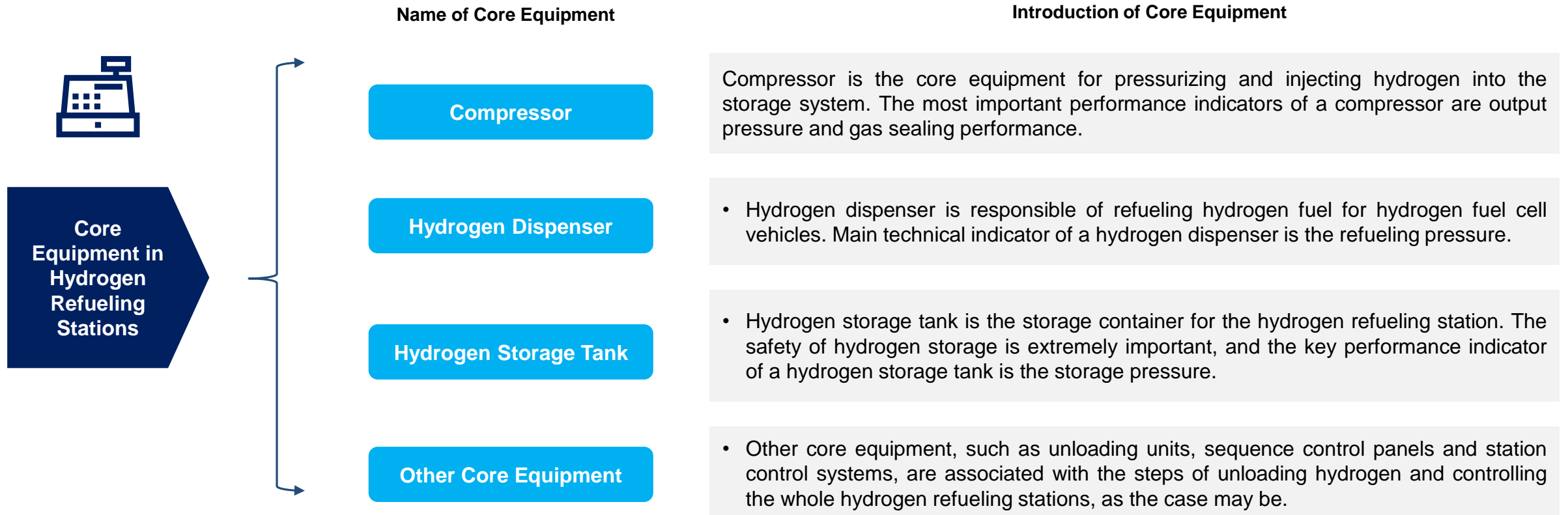
- 1 Overview of the Hydrogen Energy Industry
- 2 Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry
- 3 Overview of Core Equipment for Hydrogen Refueling Station Industry**
- 4 Overview of Core Equipment for Liquid Hydrogen Industry
- 5 Overview of the Water Electrolysis Hydrogen Production Equipment Industry
- 6 Appendix



# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Overview of Core Equipment in Hydrogen Refueling Stations

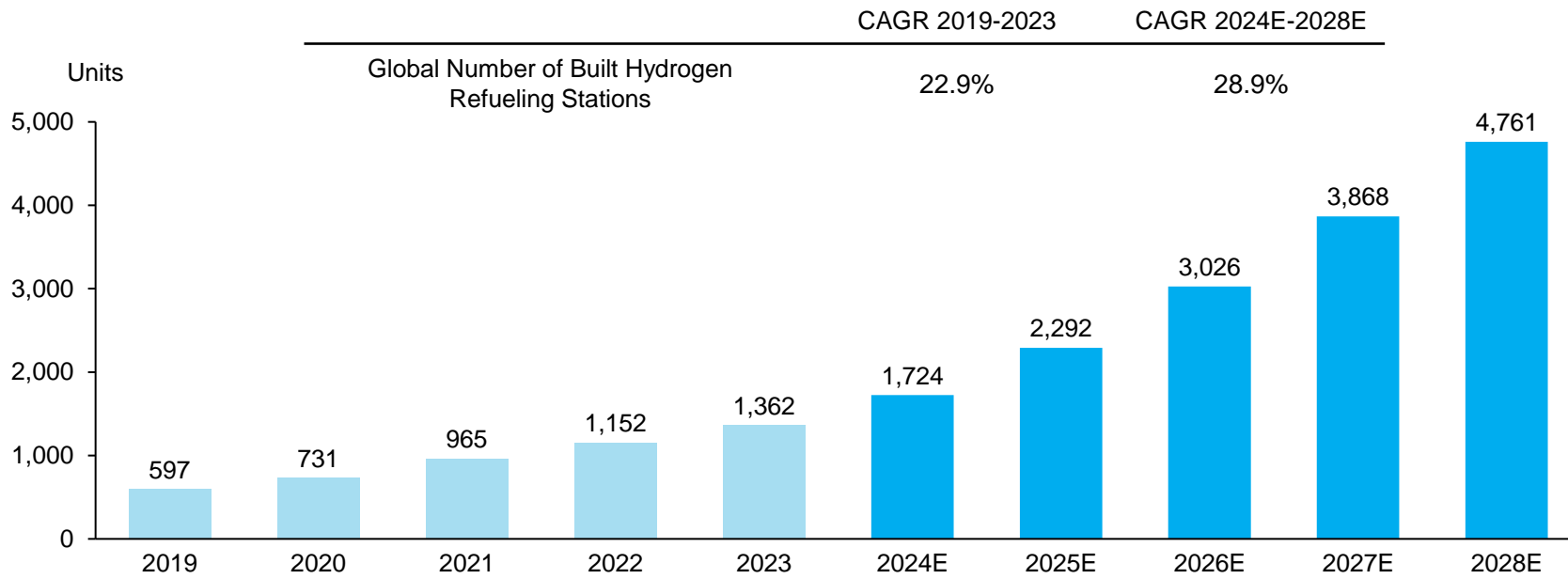
- A hydrogen refueling station typically consists of a compression system, a storage system and a refueling system. These systems are used in the compression, storage and refueling process of hydrogen. **The core equipment in hydrogen refueling stations include compressors, hydrogen dispensers, hydrogen storage tanks and other core equipment, such as unloading units, sequence control panels and station control systems.** Among them, compressors, hydrogen dispensers and hydrogen storage tanks are the three major equipment accounting for over 80% of the costs in core equipment in hydrogen refueling stations. Below sets forth a brief introduction of core equipment in hydrogen refueling stations:



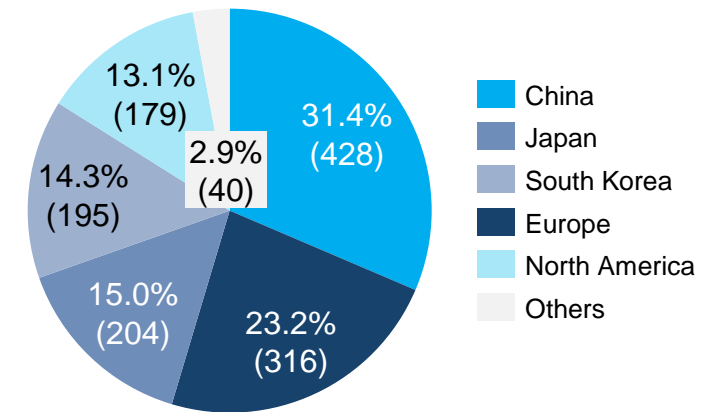
# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Global Built Hydrogen Refueling Stations

Number of Built Hydrogen Refueling Stations (Global), 2019-2028E



Number of Built Hydrogen Refueling Stations by Regions (Global), 2023



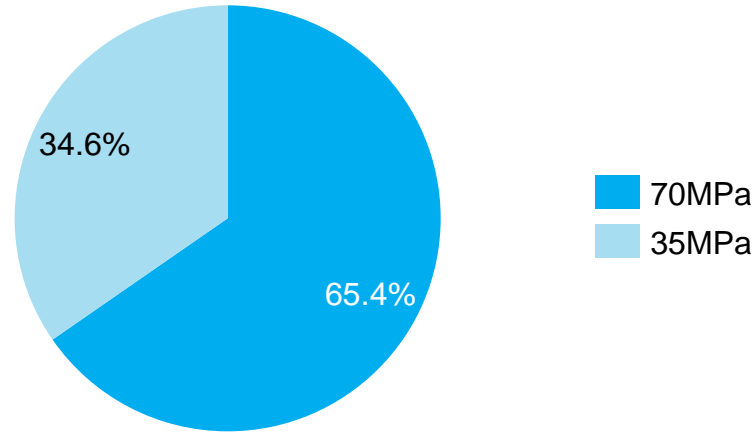
- Number of global built hydrogen refueling stations have exceeded 1,000 units during 2022. Also, the proportion of co-constructed stations is increasing, reducing the cost of building hydrogen refueling stations and pushing the market to develop at a sustained pace. With supportive policies and increasing downstream applications, number of global built hydrogen refueling stations increased from 597 units in 2019 to approximately 1,362 units in 2023, with a CAGR of 22.9%. In the future, since the growth of hydrogen fuel cell vehicles (HFCVs) will drive the development of hydrogen refueling stations, number of global built hydrogen refueling stations is expected to increase from 1,724 units in 2024 to 4,761 units in 2028, with a CAGR of 28.9%.
- In 2023, China, Europe and Japan are the three largest regions with the number of built hydrogen refueling stations, with 428, 316 and 204 units, respectively. In the future, driven by implementations of pilot programs, supportive policies and enormous potential market size of hydrogen fuel cell vehicles in China, China will remain as the global largest market in terms of number of built hydrogen refueling stations, with a hydrogen refueling station network that far exceeds that of other countries. Promoted by the recent energy crisis and carbon neutrality goals, Europe will continue its expansion on hydrogen refueling station construction. As one of the earliest countries to develop the hydrogen energy industry, Japan will remain as one of the major regions in terms of number of built hydrogen refueling stations in the future.



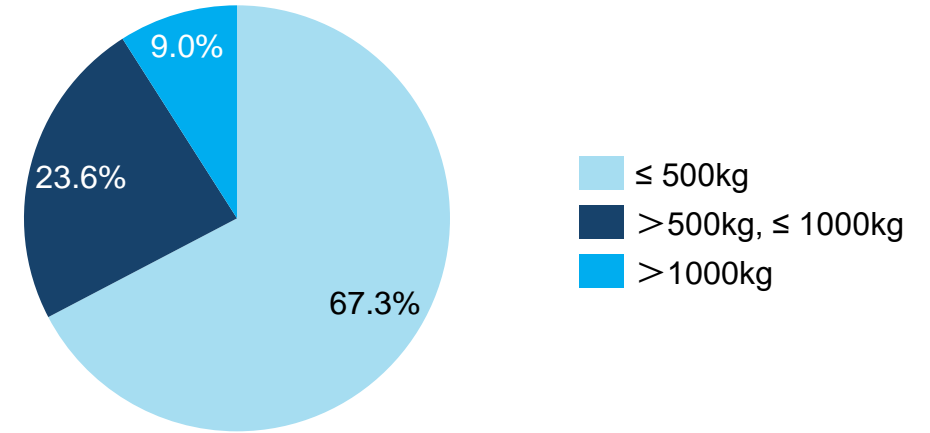
# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Global Built Hydrogen Refueling Stations by Refueling Pressure Level and by Refueling Capacity

Number of Built Hydrogen Refueling Stations by Refueling Pressure Level (Global), 2023



Number of Built Hydrogen Refueling Stations by Refueling Capacity (Global), 2023



Notes: 1. The hydrogen refueling stations with both 35MPa and 70MPa refueling pressure level are counted as 70MPa hydrogen refueling stations only; 2. Liquid hydrogen refueling stations are not included.

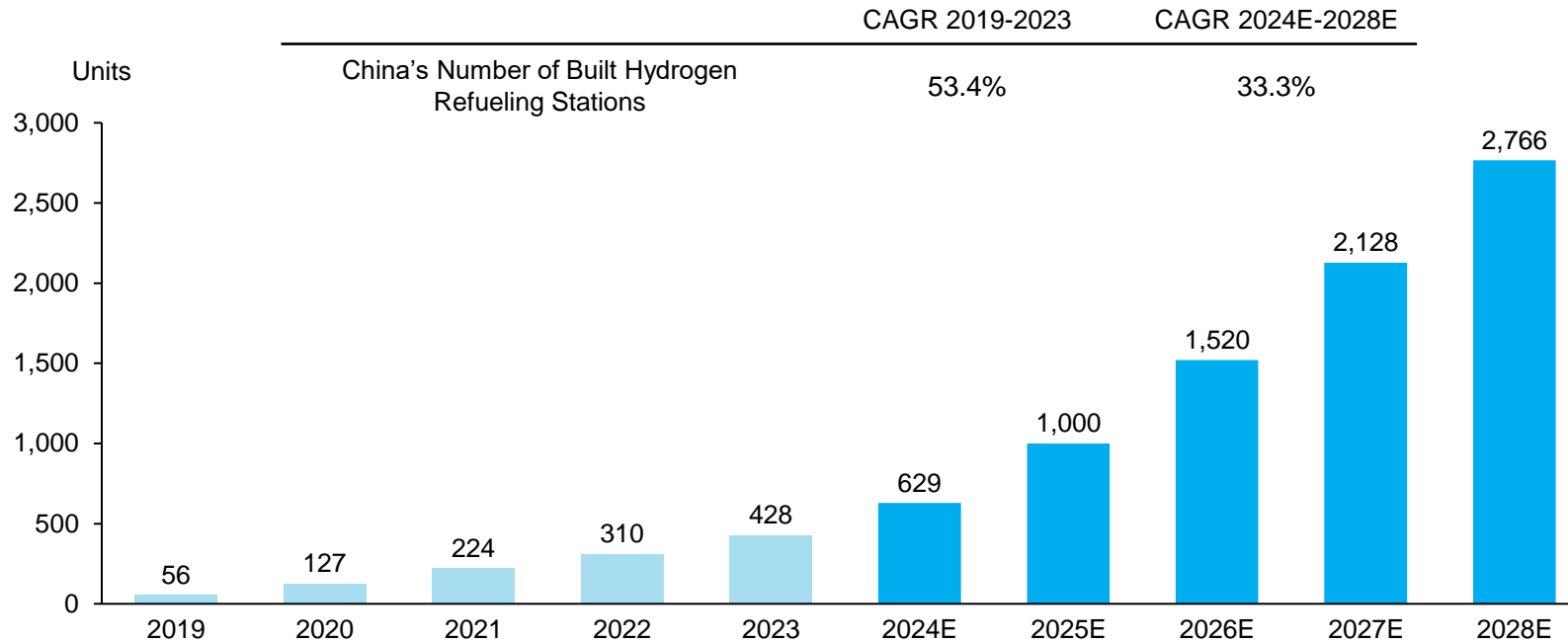
Notes: Refueling capacity is calculated based on time period of 12 hours.

- Hydrogen refueling stations can be classified into 35MPa and 70MPa by refueling pressure level. When hydrogen is supplied at a pressure of 35MPa, the working pressure of the hydrogen compressor can reach 45MPa, which is generally used for commercial vehicles. When hydrogen is supplied at a pressure of 70MPa, the working pressure of the hydrogen compressor can reach 98 MPa, which is generally used for passenger vehicles. Since China mainly develops commercial hydrogen fuel cell vehicles, 35MPa hydrogen refueling stations are mainly distributed in China, while overseas regions deploy 70MPa hydrogen refueling stations to support the development of passenger hydrogen fuel cell vehicles. In 2023, 35MPa hydrogen refueling stations accounted for 34.6% of the total number of global built hydrogen refueling stations while 70MPa hydrogen refueling stations accounted for 65.4%.
- In terms of refueling capacity, hydrogen refueling stations can be classified into 1) ≤ 500kg, 2) >500kg and ≤1,000kg, 3) > 1,000kg. Most hydrogen refueling stations built several years ago are ≤ 500kg, especially in Japan and Europe as the space and construction area in the center of city is limited. The refueling capacity of most demonstration hydrogen refueling stations in China were ≤ 500kg, while recently the number of large refueling capacity hydrogen refueling stations has begun to increase. In 2023, the number of global built hydrogen refueling stations with the hydrogen refueling capacity of ≤ 500kg, >500kg and ≤1,000kg, > 1,000kg accounted for around 67.3%, 23.6% and 9.0% of the total number, respectively.

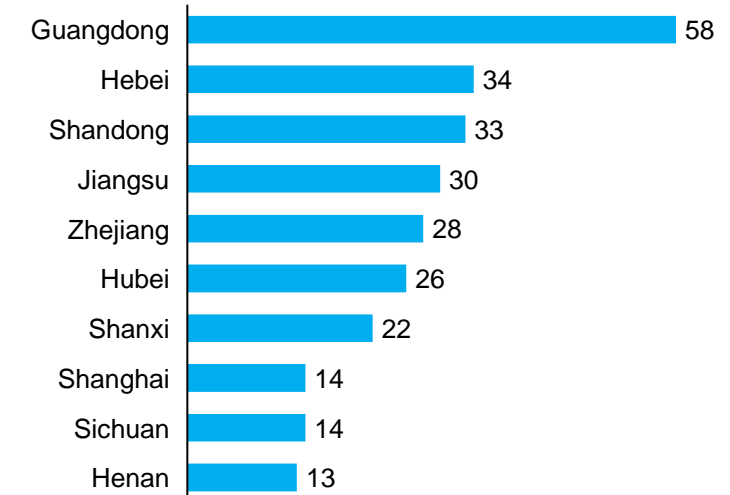
# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## China's Built Hydrogen Refueling Stations

Number of Built Hydrogen Refueling Stations (China), 2019-2028E



Top 10 Provinces/Cities by Number of Built Hydrogen Refueling Stations (China), 2023

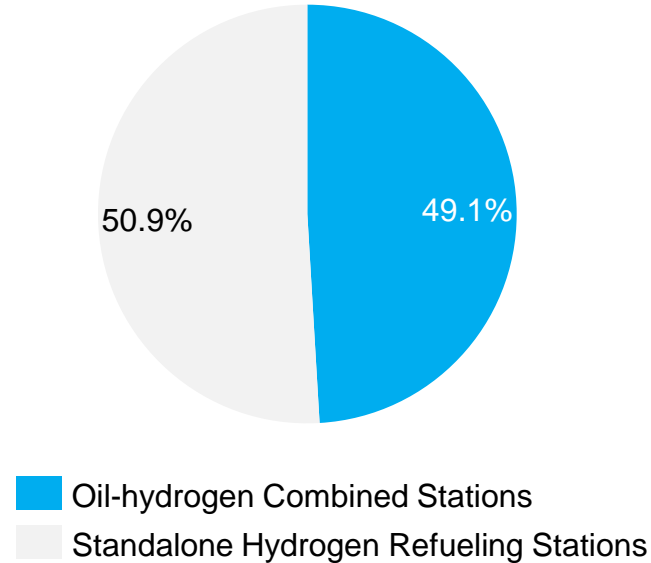


- China's built hydrogen refueling stations have experienced rapid growth since 2019. By the end of 2023, China's Ministry of Industry and Information Technology (MIIT) has approved five major hydrogen demonstration city clusters, with the goal of promoting the development of the hydrogen industry in China, which will also boost the construction of hydrogen refueling stations. China's built hydrogen refueling stations increased from 56 units in 2019 to approximately 428 units in 2023, with a CAGR of 53.4%. In the future, in accordance with the goal of "Energy Saving and New Energy Vehicle Technology Roadmap 2.0" (《节能与新能源汽车技术路线图2.0》), China's built hydrogen refueling stations will reach 1,000 units in 2025. Thus, it is expected that China's built hydrogen refueling stations will increase from 629 units in 2024 to 2,766 units in 2028, with a CAGR of 33.3%.
- In 2023, Guangdong province remained as the province with the most built hydrogen refueling stations, followed by Hebei province and Shandong province. In the future, with the construction and development of the major hydrogen demonstration city clusters, China's built hydrogen refueling stations will form a firm infrastructure basis for the hydrogen industry, with increasing hydrogen refueling stations scattering in multiple provinces around the country.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

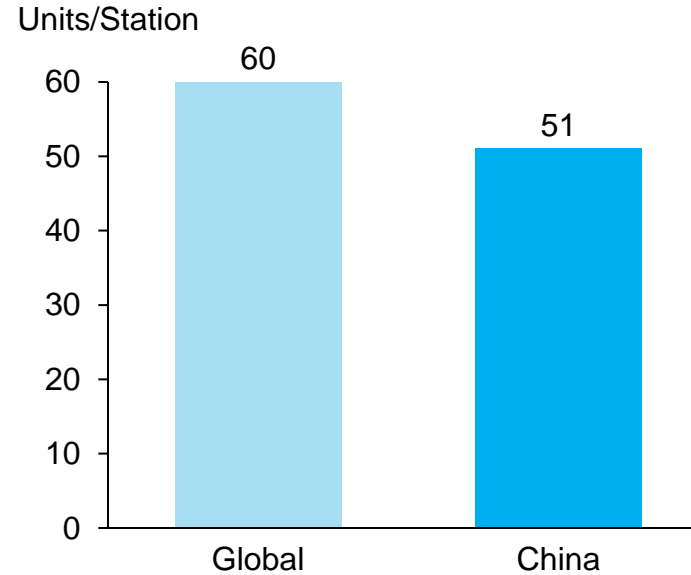
## China's Proportion of Built Oil-hydrogen Combined Stations and HFCVs per Station

Proportion of Built Oil-hydrogen Combined Stations (China), 2023



- Oil-hydrogen combined stations represent that the hydrogen refueling station is constructed with gas station. Advantages of oil-hydrogen combined stations include effectively solving the planning problems of hydrogen refueling stations, elevating the operational efficiency of hydrogen refueling stations, and keeping close relationship with the end customer. In 2023, the proportion of built oil-hydrogen combined stations in China accounts for 49.1% of the market in China, while the proportion will continue to increase in the future since majority of the newly built hydrogen refueling stations is the oil-hydrogen combined stations in 2023.

HFCVs per Hydrogen Refueling Station (Global and China), 2023



Notes: HFCVs per hydrogen refueling station represents the amount of HFCVs each station serve for. This parameter is calculated through dividing the hydrogen refueling stations in operation by the ownership of HFCVs.

- HFCVs per hydrogen refueling station reflects the utilization rate of the hydrogen refueling station and the phenomenon of economics of scale in which average cost serving HFCVs by hydrogen refueling station decreases as the popularity of HFCVs increases. In 2023, China has relatively low rate of HFCVs per hydrogen refueling station compared to other regions, especially United States and South Korea, these two countries' hydrogen refueling stations have high utilization rate with the value of HFCVs per hydrogen refueling station exceeding 100. Therefore, China's market is expected to reflect higher potential market growth in the future.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

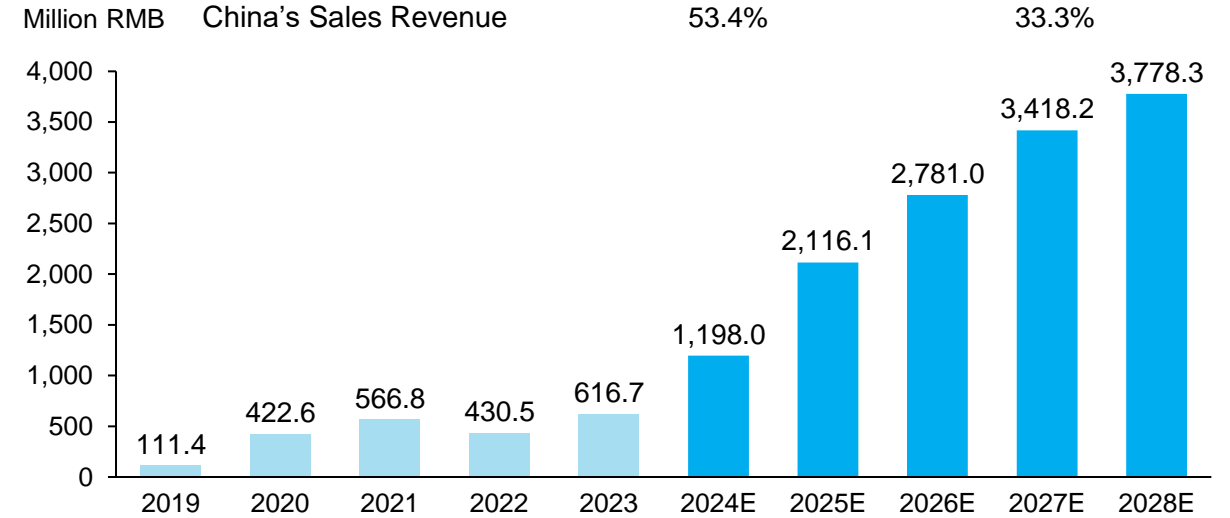
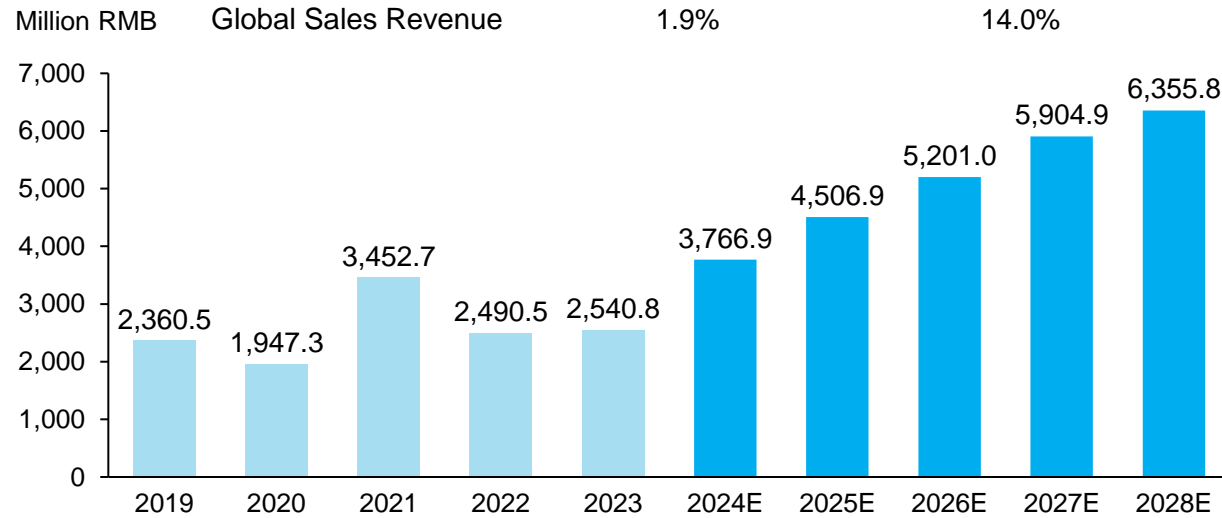
## Market for Core Equipment in Newly Built Hydrogen Refueling Stations

Sales Revenue of Core Equipment in Newly Built Hydrogen Refueling Stations (Global), 2019-2028E

Sales Revenue of Core Equipment in Newly Built Hydrogen Refueling Stations (China), 2019-2028E

CAGR 2019-2023      CAGR 2024E-2028E

CAGR 2019-2023      CAGR 2024E-2028E

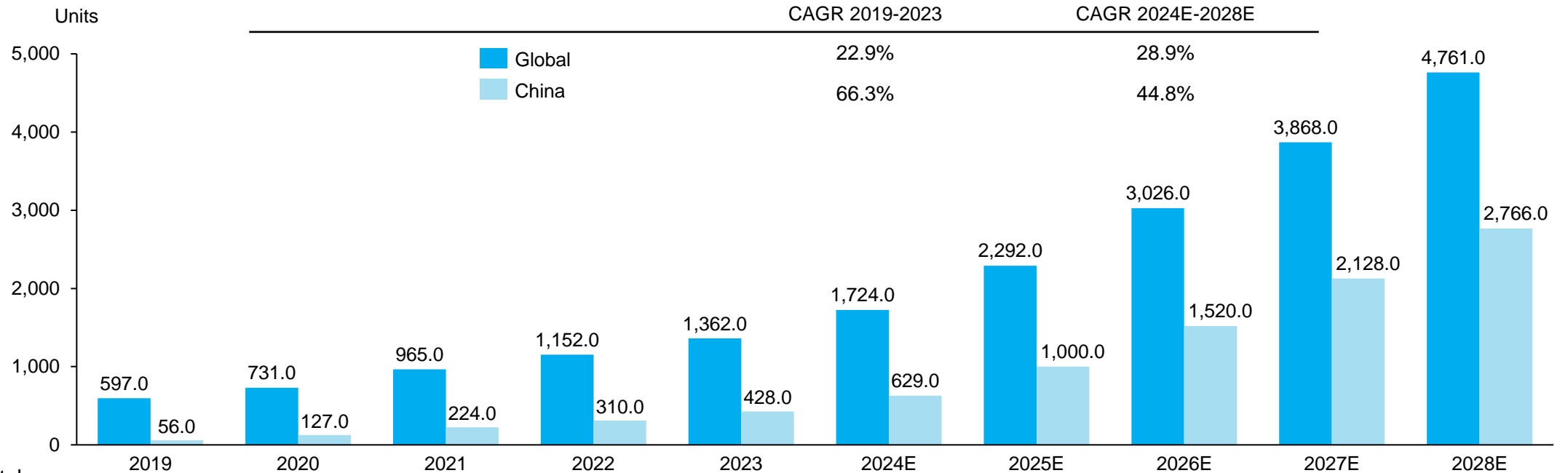


- Driven by the development of the hydrogen refueling stations, the market size of global core equipment in newly built hydrogen refueling stations by sales revenue reached RMB2,540.8 million in 2023. Meanwhile, China, the emerging hydrogen market with strong supportive policies, has witnessed an obvious development of hydrogen infrastructure and relevant equipment over the past few years. The market size of core equipment in newly built hydrogen refueling stations by sales revenue in China increased from RMB111.4 million in 2019 to approximately RMB616.7 million in 2023, with a CAGR of 53.4%.
- Beijing, Shanghai, Guangdong, Henan and Hebei has announced the development plan aiming at operating 74, 70, 200, 80 and 100 hydrogen refueling stations in 2025, respectively. Driven by the construction of these hydrogen fuel cell vehicle demonstration city clusters as well as the increasing demand from hydrogen fuel cell vehicles across China, a surge in the deployment of core equipment is anticipated in newly constructed hydrogen refueling stations throughout the country in the forthcoming years. Therefore, the market size of core equipment in newly built hydrogen refueling stations by sales revenue in China is expected to increase from RMB1,198.0 million in 2024 to RMB3,778.3 million in 2028, with a CAGR of 33.3%. The proportion of the market for China's core equipment in newly built hydrogen refueling stations in the world will reach over 59% in 2028.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Global and China's Built Hydrogen Refueling Stations

Cumulative Number of Built Hydrogen Refueling Stations (Global and China), 2019-2028E



Incremental Number of Newly Built Hydrogen Refueling Stations

Global	110	134	234	187	210	362	568	734	842	893
China	20	71	97	86	118	201	371	520	608	638

Source: (1) International Energy Agency (IEA), (2) Frost & Sullivan, (3) Fuel Cell Commercialization Conference of Japan, (4) Hydrogen Council, (5) The State Council of the People's Republic of China, (6) Official Website of Provinces/Municipality Governments, and (7) Interviews with industry experts by Frost & Sullivan.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

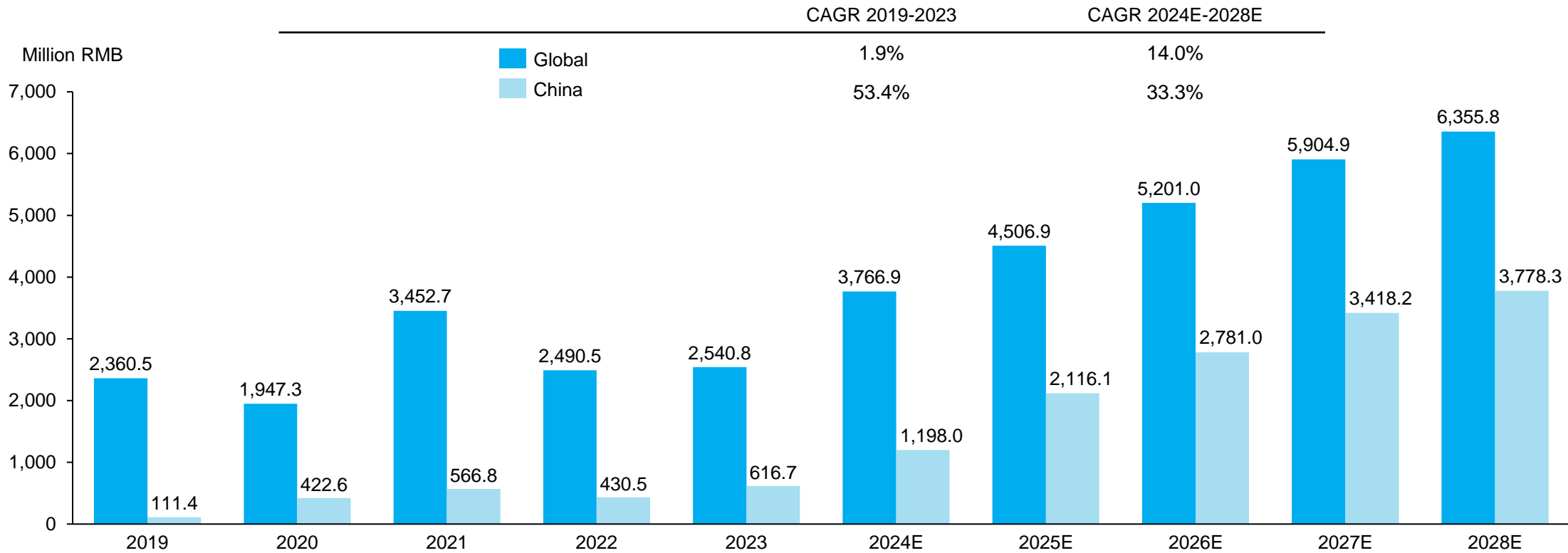
## Global and China's Built Hydrogen Refueling Stations

- With supportive policies and increasing downstream applications, the global and China's hydrogen refueling stations markets have experienced rapid growth in the past five years. However, the number of hydrogen refueling stations built in China is relatively small at present. Specifically, as at the end of 2023, there were approximately 105.8 thousand fossil fuel gas stations in China, while there were only 428 hydrogen refueling stations built across the country. This was mainly because the hydrogen energy industry in China is still in its early stage of commercialization. In the future, China is expected to remain as the world's largest market in terms of number of the hydrogen refueling stations built with the scale of the hydrogen refueling station network that far exceeds that of other countries.
- The incremental number of global and China's newly built hydrogen refueling stations surged from 110 and 20 units in 2019 to 210 and 118 units in 2023, respectively. Driven by supportive policies on the construction of hydrogen energy infrastructure, it is expected that the growth trend of hydrogen refueling stations will continue in the future. The incremental number of global and China's newly built hydrogen refueling stations are expected to reach 893 and 638 units in 2028 from 362 and 201 units in 2024.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Market for Core Equipment in Newly Built Hydrogen Refueling Stations

Sales Revenue of Core Equipment in Newly Built Hydrogen Refueling Stations (Global and China), 2019-2028E



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



# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Market Drivers and Developing Trends of Core Equipment in Hydrogen Refueling Stations

### Policies support the global and China's hydrogen refueling stations industries

Major countries and regions around the world have put forward clear plans and deployments for the development of hydrogen refueling station. For example, Japan has published the “Hydrogen Basic Strategy”, which plans to reach 900 hydrogen refueling stations by 2030. The United States is focusing on California for its hydrogen refueling station layout, with plans to achieve 1,000 hydrogen refueling stations by 2030. Korea Hydrogen Economy Roadmap 2040 plans to build 1,200 hydrogen charging stations in 2040 in South Korea. In China, the “Energy-Saving and New Energy Vehicle Technology Roadmap 2.0” (《節能與新能源汽車技術路線圖2.0》) proposes to build 1,000 hydrogen refueling stations by 2025 and 5,000 hydrogen refueling stations by 2030-2035.

### Promotion of hydrogen fuel cell vehicles drives the popularization of hydrogen refueling stations

With the promotion of hydrogen fuel cell vehicles in the world and China, the construction of hydrogen refueling stations is accelerating, and the number of hydrogen refueling stations put into operation will also realize rapid growth. Meanwhile, the construction of China's five city clusters for demonstration application of fuel cell vehicles is also accelerating, the core technologies are constantly evolving, and the hydrogen energy industry chain is gradually being improved, which in turn will lead to a peak period for the construction and operation of hydrogen refueling stations, thereby driving the growth of the core equipment in hydrogen refueling stations.

### Technology of core equipment in hydrogen refueling stations will be further improved

Currently, China still faces some disparities with foreign industry peers in key technologies and equipment for hydrogen refueling stations. Looking ahead, China aims to develop the integration of high-pressure gaseous hydrogen storage with liquid hydrogen storage and refueling technologies. To optimize the utilization of land resources and operational efficiency, it is likely that there will be an increasing number of integrated energy stations in the future, with integrated oil and gas mixed stations representing a prominent model.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Key Entry Barriers to Providers of Equipment for Hydrogen Refueling Stations and Related Products in China

1

### Technological Barrier

- Energy-saving hydrogen refueling technology and hybrid pressurized multi-stage filling technology represent the key technologies for leading providers of core equipment for hydrogen refueling stations and related products, requiring rich technical reserves and robust R&D capabilities to constantly enhance the safety and performance of the stations.

2

### Equipment Production Capacity Barrier

- The performance parameters of the compressor, hydrogen dispenser and hydrogen storage tanks determine the overall refueling capacity and storage capacity of a hydrogen refueling station. Providers of equipment for hydrogen refueling stations and related products need to match the complex equipment parameters and equipment quantities under the condition of the determined station scale, in order to achieve the optimal and most economical equipment configuration for the hydrogen refueling stations.

3

### Customer Barrier

- The construction of hydrogen refueling stations is facing challenges, including relatively stable customer base and difficulty in obtaining long-term customer cooperation. Further, oil-hydrogen combined station has become an emerging mode of the newly built hydrogen refueling stations in China in recent years. Since most oil-hydrogen combined stations in China are constructed by leading oil or gas state-owned companies, durable and stable business partnership with these state-owned energy companies become necessary for the providers of equipment for hydrogen refueling stations and related products.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

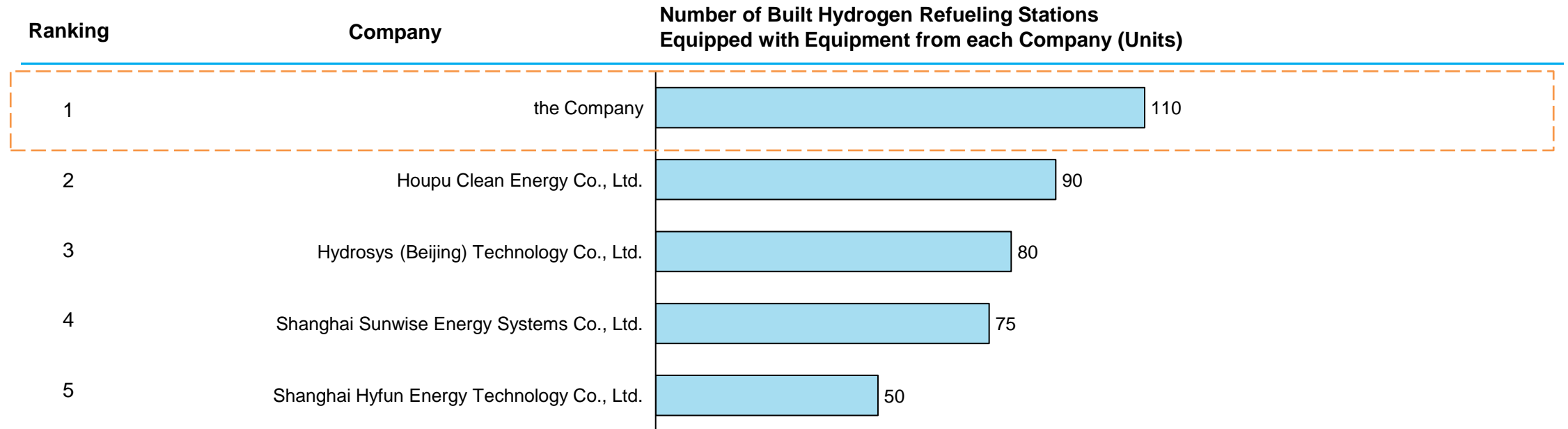
## Price Analysis of Core Equipment in Hydrogen Refueling Stations in China

- Driven by technological advancements and economies of scale, the price of core equipment for hydrogen refueling stations with equivalent refueling pressure and capabilities in China has experienced a downward trend over the past few years. However, in 2020, influenced by the COVID-19 pandemic, there was a slight increase in the price of core equipment for hydrogen refueling stations in China. Looking ahead, as the localization capabilities of core equipment for hydrogen refueling stations continue to improve and the number of stations being built grows, it is anticipated that the price of such equipment in China will further decrease. However, the construction of 70MPa hydrogen refueling stations and liquid hydrogen refueling stations will generate increased demand for relevant core equipment, which typically carries higher prices. This will consequently affect the overall average price of core equipment for hydrogen refueling stations in China.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Competitive Landscape of Providers of Equipment for Hydrogen Refueling Stations and Related Products

Top Five Providers of Equipment for Hydrogen Refueling Stations and Related Products  
by Number of the Built Hydrogen Refueling Stations Equipped with each Company's Equipment (China), 2023



- By the end of 2023, the number of hydrogen refueling stations built in China reached 428 units, of which 110 hydrogen refueling stations were equipped with our equipment for hydrogen refueling stations and related products, accounting for 25.7% of the total built hydrogen refueling stations. We ranked first among all providers of equipment for hydrogen refueling stations and related products in China in 2023.

# Overview of Core Equipment for Hydrogen Refueling Stations Industry

## Major Competitors of Providers of Equipment for Hydrogen Refueling Stations and Related Products

Company Name	Year of Establishment /Headquarter	Listed/Unlisted	Business Introduction
Houpu Clean Energy Co., Ltd. 厚普清洁能源（集团）股份有限公司	2005, Chengdu, Sichuan Province, China	Listed (SZ.300471)	<ul style="list-style-type: none"> <li>The company is a leading clean energy company in China, devoting to provide integrated solutions in clean energy and related application fields. Their products for equipment in hydrogen refueling stations include compressors, hydrogen dispensers, hydrogen storage tanks, hydrogen unloading column, sequence panels, etc. Their customers include Sinopec, Petro China and CNOOC, major gas groups, transportation groups, ports and terminals, etc.</li> </ul>
Hydrosys (Beijing) Technology Co., Ltd 北京海德利森科技有限公司	2001, Beijing, China	Unlisted	<ul style="list-style-type: none"> <li>The company is a high-pressure, ultra-high-pressure system integrated service provider of research and development, production, sales and service, committed to provide a full range of customized hydrogen refueling station core equipment, gas booster system, high-pressure detection system and other integrated solutions. They focus on the core technology of high-pressure fluid application, operating in a wide range of pressures from 22MPa to 90MPa, which can be customized according to the different amount of hydrogenation and different application scenarios of the customers, providing potable and stationary solutions to meet the diverse needs of customers.</li> </ul>
Shanghai Sunwise New Energy Systems Co., Ltd. 上海舜华新能源系统有限公司	2004, Shanghai, China	Unlisted	<ul style="list-style-type: none"> <li>The company has mastered the core technologies for the processing of high-pressure hydrogen. It aims to become a leading provider of hydrogen system overall solutions, core equipment, and hydrogen supply ecosystem in China. The core team of the company has more than 10 years of technology accumulation in the field of hydrogen energy. Their products for equipment in hydrogen refueling stations mainly include skid-mounted hydrogen refueling station, hydrogen dispensers, H2 unloading column, SCADA system, etc.</li> </ul>
Shanghai Hyfun Energy Technology Co., Ltd. 上海氢枫能源技术有限公司	2016, Shanghai, China	Unlisted	<ul style="list-style-type: none"> <li>The company provides related products and services such as hydrogen production, magnesium-based solid hydrogen storage and transportation, hydrogen refueling station construction and operation, and hydrogen fuel cell vehicle operation. Their products for equipment in hydrogen refueling stations include compressors, hydrogen dispensers, hydrogen unloading column, sequence panels, etc.</li> </ul>

# Agenda

- 1 Overview of the Hydrogen Energy Industry
- 2 Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry
- 3 Overview of Core Equipment for Hydrogen Refueling Station Industry
- 4 Overview of Core Equipment for Liquid Hydrogen Industry**
- 5 Overview of the Water Electrolysis Hydrogen Production Equipment Industry
- 6 Appendix



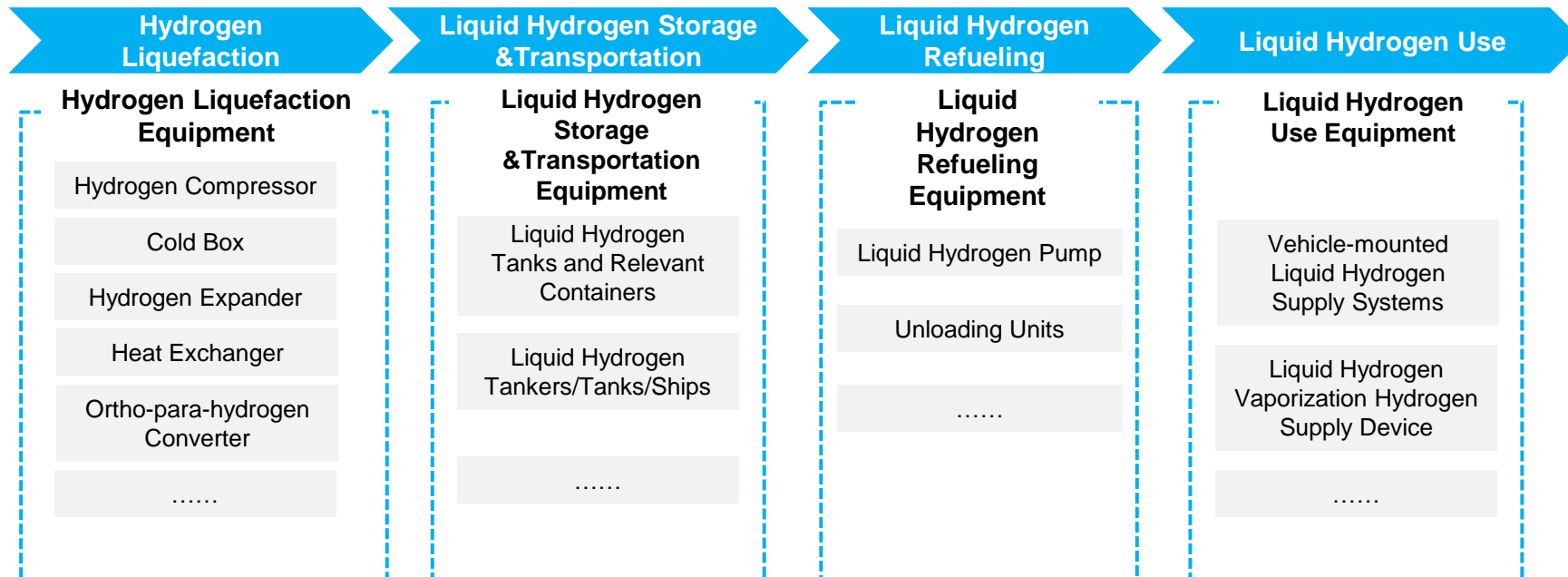
# Overview of Core Equipment for Liquid Hydrogen Industry

## Overview of the Liquid Hydrogen Industry

### Overview of Liquid Hydrogen Industry

- Liquid hydrogen industry encompasses activities related to hydrogen liquefaction, as well as storage, transportation, refueling and use of liquid hydrogen. During the hydrogen liquefaction process, cooling and liquefaction that converts gaseous hydrogen into liquid hydrogen are important as hydrogen is a gas at ambient temperature and pressures. By reducing the temperature to cryogenic levels, hydrogen undergoes a transition from gas to liquid and a significant reduction in volume, which allows for an increasingly compact and efficient solution for high energy density required applications. Liquid hydrogen has the advantage that extremely high hydrogen storage densities can be attained at atmospheric pressure. The density of saturated liquid hydrogen at one bar is approximately 70 kg/m<sup>3</sup>. Therefore, liquid hydrogen is a suitable solution to realize large-scale hydrogen storage and long-distance transportation. In addition, liquid hydrogen has the features of high purity and ultra-low temperature, which has been applied to high-end manufacturing and superconducting energy storage in the developed countries, showcasing extensive prospects for broad application.
- Core equipment of liquid hydrogen industry mainly includes hydrogen liquefaction equipment, equipment for storage and transportation of liquid hydrogen, and liquid hydrogen refueling equipment. The chart below illustrates the core equipment used for the industrial chain of liquid hydrogen:

### Core Equipment Along Supply Chain of Liquid Hydrogen Industry





# Overview of Core Equipment for Liquid Hydrogen Industry

## Hydrogen Liquefaction

The technology for hydrogen liquefaction involves the process of converting hydrogen from a gaseous to a liquid state. Based on different liquefaction methods, there are three common hydrogen liquefaction technologies: pre-cooling Linde-Hampson method, Claude method and Brayton method.

Specifically, the Linde-Hampson method is mainly suitable for small-scale liquid hydrogen production due to its drawbacks such as low efficiency, high energy consumption per unit and low liquefaction output rates. Compared with helium expansion Claude method, hydrogen expansion Claude method uses a compressor to compress hydrogen gas into high-pressure gas under adiabatic conditions, and then it undergoes cooling and expansion processes to liquefy the gas. It is particularly suitable for large-scale liquid hydrogen production with a capacity exceeding five tons per day. Currently, most of the world's large-scale hydrogen liquefaction facilities are based on the hydrogen expansion Claude method.

# Overview of Core Equipment for Liquid Hydrogen Industry

## Storage and Transportation of Liquid Hydrogen

Storage and transportation of liquid hydrogen refer to the technology and process of storing and transporting hydrogen in a liquid state. In such way, hydrogen is typically stored at extremely low temperature where it exists as clear, colorless liquid with a low density. Cryogenic liquid hydrogen storage, which is a form of physical storage, involves cooling hydrogen to below  $-253^{\circ}\text{C}$  to transform into liquid state. The liquefied hydrogen is subsequently stored in specially designed cryogenic vacuum containers. Cryogenic liquid hydrogen storage typically employs specially designed double-layer insulated storage tanks to minimize the impact of external heat conduction on liquid hydrogen. The key to cryogenic liquid hydrogen storage is the design and performance of the liquid hydrogen storage tanks. Due to technological constraints, the storage and transportation technology of liquid hydrogen in China are primarily applied in the aerospace and military industry. Although liquid hydrogen containers have been used in aerospace field, the current high manufacturing cost brings challenges for widespread application and use of liquid hydrogen for civil use in China.

The transportation of cryogenic liquid hydrogen include liquid hydrogen tankers, liquid hydrogen tanks, and liquid hydrogen ships. Liquid hydrogen tanks are the core equipment for cryogenic liquid hydrogen transportation, especially suitable for multimodal transportation. Due to the special characteristics of liquid hydrogen, such as extremely low boiling point, low latent heat and easy evaporation, the storage of liquid hydrogen requires the use of liquid hydrogen tanks with excellent insulation performance. As the demand for liquid hydrogen continues to grow, China's liquid hydrogen industry will require increased investment in the field of cryogenic liquid hydrogen transportation, enhanced commercialization level, in order to better adapt to the global development trend of liquid hydrogen transportation.

Source: Frost & Sullivan

# Overview of Core Equipment for Liquid Hydrogen Industry

## Market Drivers and Development Trend of Liquid Hydrogen Industry

### Increasing demand and economic advantages of liquid hydrogen

In the case of large-scale hydrogen use and long-distance transportation, liquid hydrogen has better economics than high-pressure gaseous hydrogen. The biggest advantage of liquid hydrogen compared to high-pressure gaseous hydrogen storage is its high density. The transportation capacity of a liquid hydrogen tanker is generally 2.5-3.3 tons, which is six to eight times of the single transportation capacity of a 20MPa long tube trailer for gaseous hydrogen, and the weight of a liquid hydrogen tanker is reduced by approximately 30%, which is more suitable for large-scale storage and transportation of hydrogen. Propelled by technological advancements and the increasing need for longdistance and large-capacity hydrogen transportation, liquid hydrogen industry is expected to continued to grow in the future. As the scale of liquid hydrogen increases, the unit cost of hydrogen liquefaction and related storage and transportation equipment will further decrease.

### Domestic substitution of core equipment of liquid hydrogen

For a long time, due to the lack of complete standards and relevant regulations, the application of liquid hydrogen in China has been mainly limited to the aerospace and military fields, hindering its widespread application in the civilian field. In November 2021, the Chinese government approved and released three national standards for liquid hydrogen, covering the production, storage, transportation and application of liquid hydrogen. As the Chinese government establishes and improves liquid hydrogen standard systems, liquid hydrogen equipment manufacturers in China will further increase R&D efforts to accelerate the domestication process of core equipment, thus promoting the large-scale application of liquid hydrogen in China and realizing the domestic substitution of core equipment of liquid hydrogen.

### Increasing demand for industrial application

Unlike the United States where liquid hydrogen has been widely used in electronics, metallurgy, petrochemicals, hydrogen fuel cells and other fields, the application of liquid hydrogen in the civilian field in China is currently in its initial stage, which has large development potential in the future, especially in the fields such as hydrogen energy heavy-duty transportation, petroleum refining, electronics and high-end manufacturing. Ultrapure hydrogen is widely used in the electronics industry, petrochemical industry and high-end manufacturing industry. As an efficient and easily available ultra-low temperature medium, liquid hydrogen is expected to gradually supplant liquid helium across various sectors. This shift is particularly notable in industrial applications where liquid helium has traditionally been employed, thereby contributing to growing demand for liquid hydrogen. For example, liquid hydrogen is poised to serve as a viable replacement for liquid helium in key domains such as superconducting magnet cooling. The emerging application of liquid hydrogen in industrial sector will further stimulate the growing demand of liquid hydrogen.

# Overview of Core Equipment for Liquid Hydrogen Industry

## Entry Barrier

1

### Technical Barrier

- The technical barriers for the liquid hydrogen core equipment industry include the technologies for cryogenic heat transfer and energy-efficient expansion. Achieving and maintaining the extremely low temperature for liquefying hydrogen require specialized knowledge in cryogenics and vacuum technologies. Furthermore, the development of energy-efficient expansion technologies requires expertise in thermodynamics and mechanical engineering.

3

### Production Capabilities Barrier

- The production capacity entry barriers for the liquid hydrogen core equipment industry are formidable, stemming from the specialized nature of manufacturing processes required. The processes necessitate sophisticated production and testing equipment capable of handling cryogenic conditions, stringent quality control measures and intricate supply chain management for materials capable of withstanding extreme temperatures. Meanwhile, continuous efforts are required to establish and expand the production capacity of the liquid hydrogen core equipment to enhance economies of scale in production and cost-effectiveness.

Source: Frost & Sullivan

# Overview of Core Equipment for Liquid Hydrogen Industry

## Competitive Landscape of Liquid Hydrogen Industry in China

Before 2023, China's total production capacity of hydrogen liquefaction remained at approximately five to eight tons per day, and such liquid hydrogen liquefaction production facilities were primarily utilized in the aerospace and military sectors. Recently, multiple types of companies, including state-owned enterprises, private companies and international players are carrying out R&D, testing and production capacity construction of hydrogen liquefaction equipment in China.

In 2023, the Company successfully delivered China's first large-scale hydrogen liquefaction equipment for civilian use with the production capacity of 10 tons per day. In addition, the Company is the first company in China who uses the hydrogen expansion refrigeration hydrogen liquefaction method for civilian use. Looking forward, driven by favorable policies, the improvement of the liquid hydrogen standard system, and the development of related hydrogen liquefaction projects, China's production capacity of hydrogen liquefaction will further grow and is expected to reach 700 to 1,000 tons per day by 2030.

Similarly, due to China's small hydrogen liquefaction capacity and small domestic demand for equipment for storage and transportation of liquid hydrogen, only a few domestic companies have deployed in this field in the past. Recently, with the development of the hydrogen liquefaction technology in civilian application, several leading Chinese companies have made outstanding progress in equipment for storage and transportation of liquid hydrogen. In 2023, we successfully delivered China's first 200m<sup>3</sup> liquid hydrogen container used in a large-scale civilian use liquid hydrogen plant.

Source: Frost & Sullivan

# Agenda

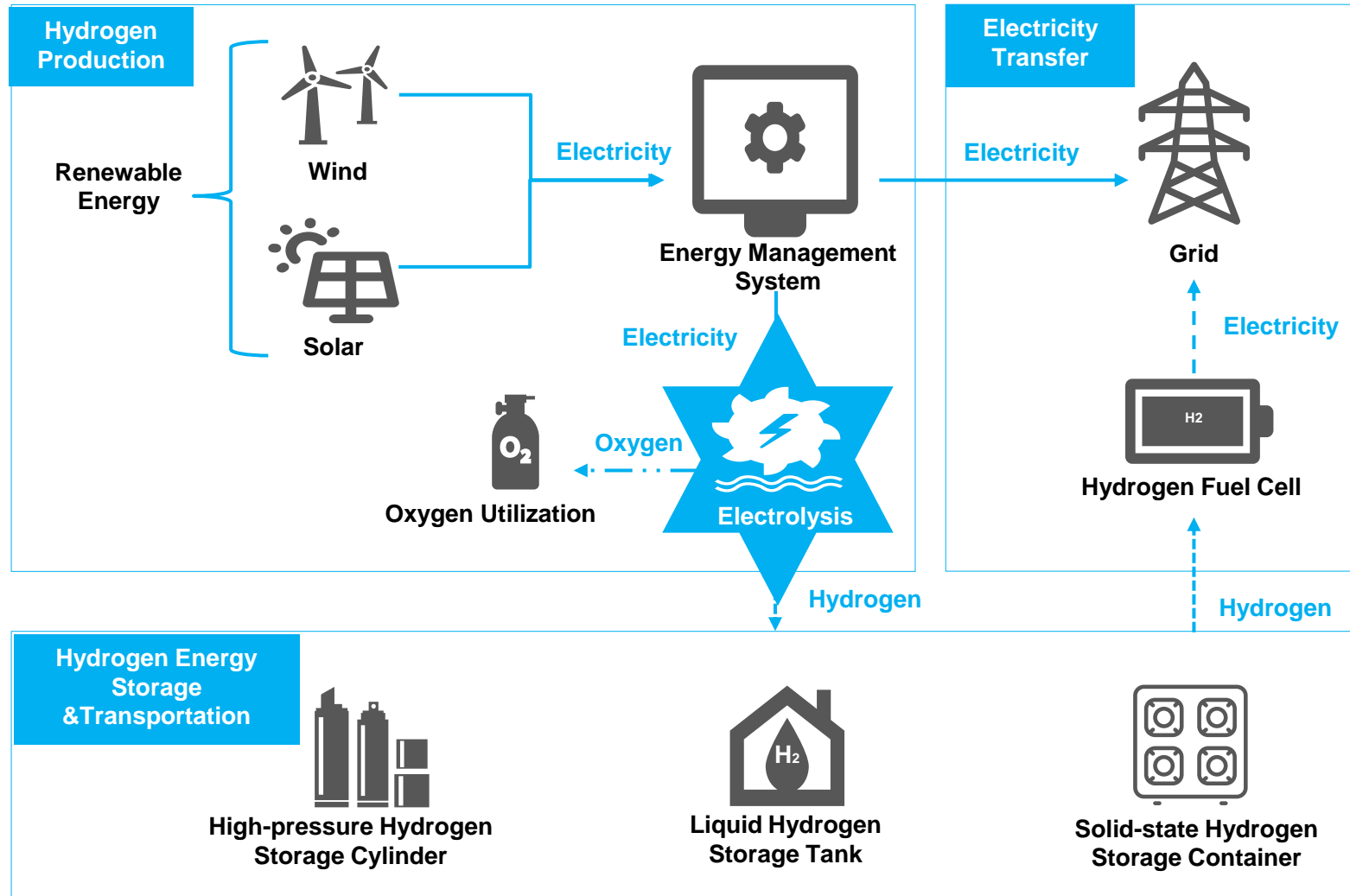
- 1 Overview of the Hydrogen Energy Industry
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# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Overview of Water Electrolysis Hydrogen Production

### Illustration of Water Electrolysis Hydrogen Production



- ❑ Water electrolysis hydrogen production involves an electrochemical process that decomposes water into hydrogen and oxygen by employing electricity. This reaction occurs in the water electrolysis hydrogen production equipment. The core components in a water electrolysis hydrogen production equipment mainly consist of electrolyzer and auxiliary systems, such as gas-liquid separation system and hydrogen purification system, among others.
- ❑ Electrolyzer is the core component of water electrolysis hydrogen production equipment, accounting for a majority of the overall equipment cost. Electrolytic cells utilize electric current to separate water molecules into hydrogen and oxygen gases. Additionally, when powered by renewable energy sources, it generates hydrogen in an environmentally friendly way, which it is also named “Green Hydrogen”.
- ❑ Currently, the water electrolysis hydrogen production methods is primarily categorized into ALK water electrolysis, PEM water electrolysis, Solid Oxide Electrolysis Cell water electrolysis and AEM water electrolysis.



# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Overview of Water Electrolysis Hydrogen Production Equipment

### Comparison of Major Water Electrolysis Hydrogen Production Methods

Water Electrolysis Technology	ALK	PEM	SOEC	AEM
Separation	Diaphragm (e.g., Zirfon)	Proton exchange membrane (e.g., Nafion)	Solid oxide membrane (e.g., Ceramic)	Anion exchange membrane (e.g., Sustainion)
Cathode	NiMo-based alloys	PGMs	Ni or Stainless Steel	Transition metal-based materials
Anode	NiCo-based alloys	IrO <sub>2</sub> , RuO <sub>2</sub>	Ni or Stainless Steel	Transition metal-based materials
Current collector	Ni plate	Copper plate	Metallic	Copper plate
Bipolar plate	/	Graphite and Ti plate	Metallic	Ni or Stainless Steel plate
Electrolyte	30-40 wt% KOH	Pure water	Solid ceramic material	Pure water, alkali solution
Current density	< 0.5 A cm <sup>-2</sup>	1~2 A cm <sup>-2</sup>	0.5-1 A cm <sup>-2</sup>	1~2 A cm <sup>-2</sup>
Gas purity	> 99.5%	> 99.999%	>99.5%	>99.99%
Lifetime	~ 100 kh	< 10 kh	Varies depending on operating conditions	< 2 kh
Estimated cost	Low	Medium	High	Not available
Technology Maturity	Mature	Mature	R&D	R&D

□ With the low-cost advantage and high level of technological maturity, ALK water electrolysis technology has become the predominant approach and holds a commanding position in the world. Meanwhile, due to the high compatibility with renewable energy sources and superior electrolysis efficiency, PEM water electrolysis technology is projected to gradually emerge as the principal technology in the hydrogen production market in the future. Meanwhile, SOEC and AEM water electrolysis technologies exhibit potential for development. The two technologies are presently in the experimental, testing, and research and development phases.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Overview of Water Electrolysis Hydrogen Production Equipment

### Operating Principle of ALK Water Electrolysis

- ❑ ALK water electrolysis is a mature technology for water electrolysis. The basic principle of ALK water electrolysis involves using KOH and other alkaline aqueous solutions as the electrolyte, and non-woven fabrics (made from fluorine-containing or fluorine-chlorine polymers) as the diaphragm. Under the action of direct current, water electrolysis generates hydrogen and oxygen, which are precipitated at the cathode and anode of the electrolytic cell. While ALK water electrolysis hydrogen production technology is mature, it has issues such as lye loss, corrosion, high energy consumption, and requires more floor space.

### Operating Principle of PEM Water Electrolysis

- ❑ PEM water electrolysis is currently in the early stages of marketization. Its main components include a membrane with proton exchange capability and cathode and anode catalytic layers tightly connected to each side of the membrane. In contrast to ALK water electrolysis, PEM water electrolysis uses a proton exchange membrane as the solid electrolyte instead of a diaphragm and alkaline electrolyte. Additionally, it utilizes pure water as the feedstock for hydrogen production, avoiding potential alkali contamination and corrosion issues.

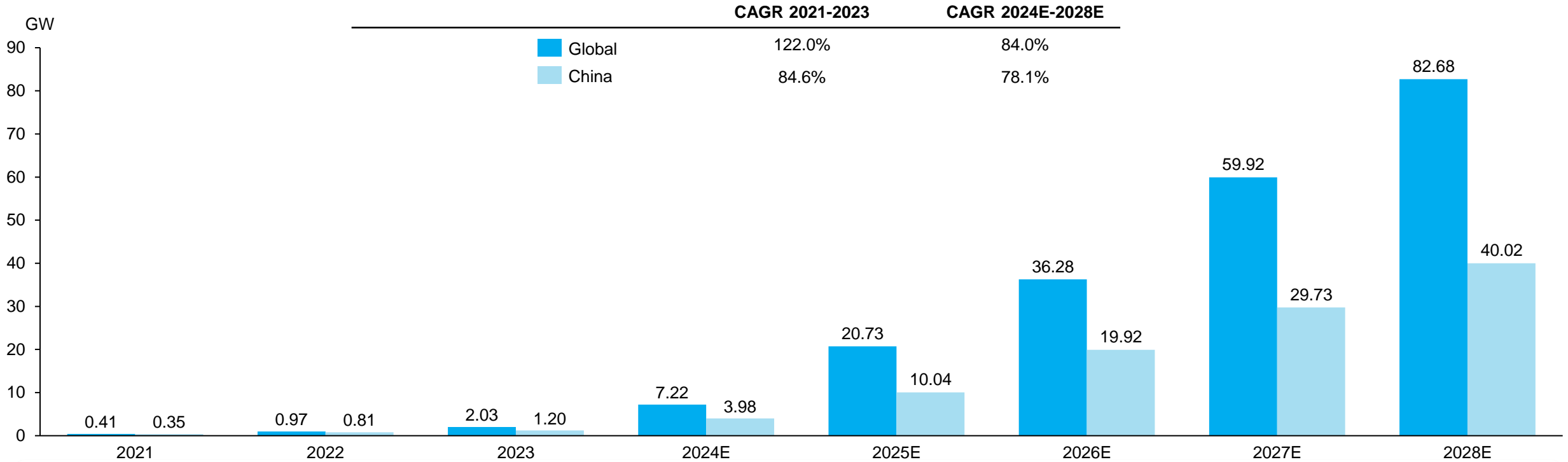
### Comparison between ALK and PEM Water Electrolysis

- ❑ Advantages of ALK water electrolysis: (i) ALK water electrolysis is a mature technology, enabling large-scale hydrogen generation; (ii) this technology is recognized as an economical method for water electrolysis hydrogen production in China, providing an optimal balance between cost-efficiency and high performance; and (iii) the domestication of ALK water electrolysis hydrogen production equipment in China is relatively high.
- ❑ Advantages of PEM water electrolysis: (i) PEM water electrolysis requires a relatively small footprint, making it highly space-efficient; and (ii) its higher adaptability to renewable energy sources stems from its ability to seamlessly handle intermittent power supply, positioning it as an ideal hydrogen production technology for integration with renewable energy systems.
- ❑ Disadvantages of ALK water electrolysis: ALK water electrolysis hydrogen production requires relatively high electricity consumption and demands a highly stable power supply infrastructure.
- ❑ Disadvantages of PEM water electrolysis: PEM water electrolysis is currently an emerging hydrogen production technology in its early commercialization phase in China, resulting in a minimal cost advantage over the more established ALK water electrolysis.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment

Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment (Global and China), 2021-2028E

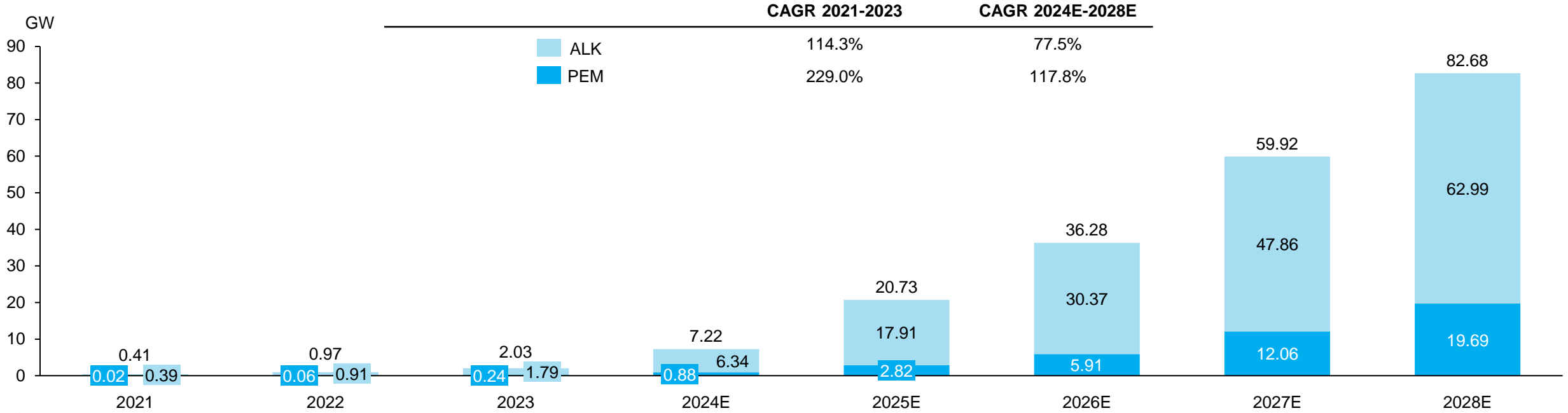


• The global water electrolysis hydrogen production equipment industry has experienced a rapid growth, driven by a growing demand for hydrogen energy. The global newly installed capacity of the water electrolysis hydrogen production equipment increased from 0.41 GW in 2021 to 2.03 GW in 2023, with a CAGR of 122.0% over the period. The global newly installed of the water electrolysis hydrogen production equipment industry is expected to increase from 7.22 GW in 2024 to 82.68 GW in 2028, with a CAGR of 84.0% over the period. Hydrogen produced by water electrolysis using renewable energy has the advantages of low-carbon and environmentally friendly, which is expected to be an important renewable energy carrier for achieving carbon neutrality. The newly installed capacity of the water electrolysis hydrogen production equipment will usher in a new growth engine in the future. The newly installed capacity of the water electrolysis hydrogen production equipment in China skyrocketed from 0.35 GW in 2021 to 1.20 GW in 2023, with a CAGR of 84.6% over the period. Looking forward, China's newly installed capacity of the water electrolysis hydrogen production equipment is expected to increase from 3.98 GW in 2024 to 40.02 GW in 2028, with a CAGR of 78.1% during the period.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology

Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology (Global), 2021-2028E

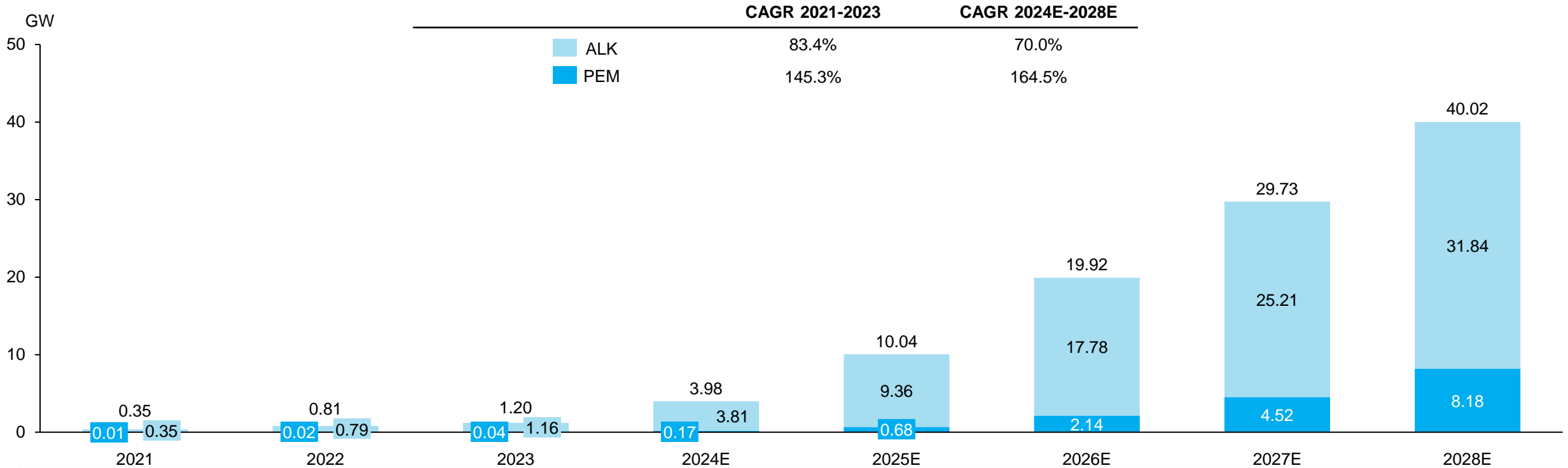


- Water electrolysis hydrogen production technologies mainly include Alkaline (ALK) water electrolysis, Proton Exchange Membrane (PEM) water electrolysis, Solid Oxide Electrolysis Cell (SOEC) water electrolysis, and Anion Exchange Membrane (AEM) water electrolysis. Among these, ALK water electrolysis technology currently dominates the global market due to its low investment costs, extended lifespan, and scalability. As a result ALK water electrolysis hydrogen production equipment has taken over the major market for the water electrolysis hydrogen production equipment worldwide. Global newly installed capacity of ALK water electrolysis hydrogen production equipment increased from 0.39 GW in 2021 to 1.79 GW in 2023, with a CAGR of 114.3% over the period. Global newly installed capacity of ALK water electrolysis hydrogen production equipment is expected to increase from 6.34 GW in 2024 to 62.99 GW in 2028, with a CAGR of 77.5% over the period.
- PEM water electrolysis technology is well-suited for a variety of hydrogen production applications, but is still in an early commercialization stage due to relatively high costs. Global newly installed capacity of PEM water electrolysis hydrogen production equipment increased from 0.02 GW in 2021 to 0.24 GW in 2023, with a CAGR of 229.0% over the period. With the increasing awareness and demand for hydrogen energy, global newly installed capacity of PEM water electrolysis hydrogen production equipment is expected to increase from 0.88 GW in 2024 to 19.69 GW in 2028, with a CAGR of 117.8% during the period.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology

Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology (China), 2021-2028E

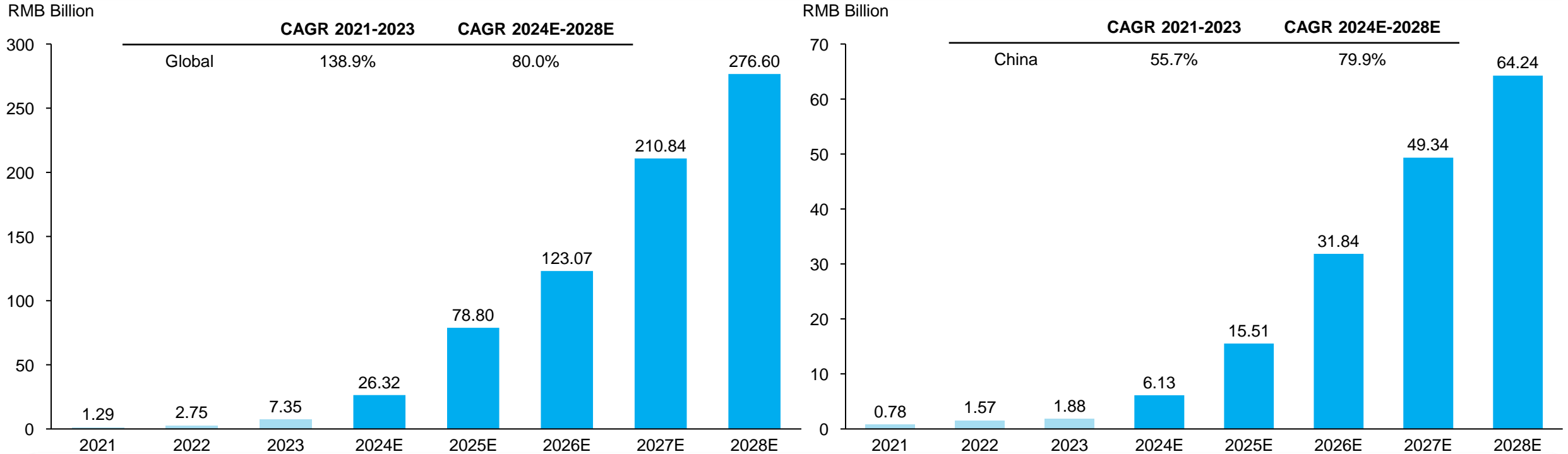


- In China, the overall cost of ALK water electrolysis hydrogen production equipment is significantly lower than PEM water electrolysis hydrogen production equipment. However, the overall efficiency of ALK water electrolysis hydrogen production equipment is lower than PEM water electrolysis hydrogen production equipment in China. With the development of the PEM water electrolysis industry chain, costs are expected to decrease, making PEM water electrolysis technology more competitive.
- Newly installed capacity of ALK water electrolysis hydrogen production equipment in China increased from 0.35 GW in 2021 to 1.16 GW in 2023, with a CAGR of 83.4% over the period, and is expected to increase to 31.84 GW in 2028, with a CAGR of 70.0% from 2024 to 2028. Newly installed capacity of PEM water electrolysis hydrogen production equipment increased from 0.01 GW in 2021 to 0.04 GW in 2023, with a CAGR of 145.3% over the period, and it is expected to increase to 8.18 GW in 2028, with a CAGR of 164.5% from 2024 to 2028.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment

Sales Revenue of Water Electrolysis Hydrogen Production Equipment (Global and China), 2021-2028E

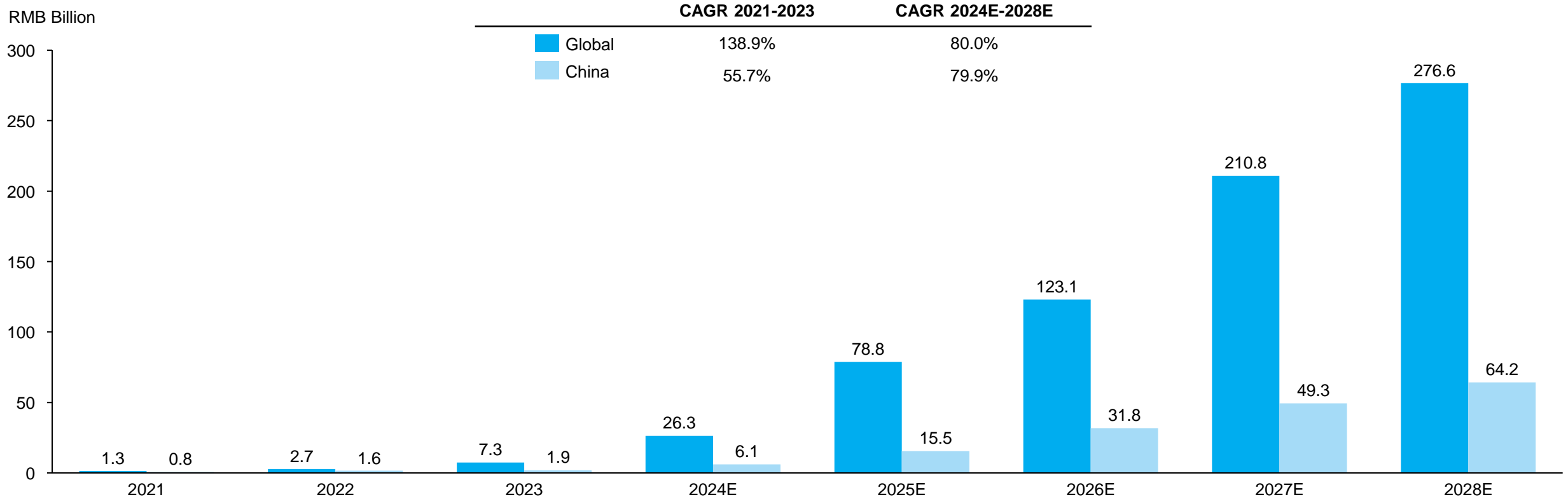


- Driven by the rising demand for hydrogen and advancements in related water electrolysis technology, the market size of the global and China's water electrolysis hydrogen production equipment industry in terms of revenue kept a steady increase and is expected to continue the growing trend in the coming years.
- The global sales revenue of water electrolysis hydrogen production equipment increased from RMB1.29 billion in 2021 to RMB7.35 billion in 2023, with a CAGR of 138.9% over the period. Driven by the rising demand for hydrogen and advancements in related technology, the global sales revenue of water electrolysis hydrogen production equipment is expected to surge from RMB26.32 billion in 2024 to RMB276.60 billion in 2028, with a CAGR of 80.0% during the period. China, a major player in the water electrolysis hydrogen production equipment market, its sales revenue of water electrolysis hydrogen production equipment increased from RMB0.78 billion in 2021 to RMB1.88 billion in 2023, with a CAGR of 55.7%. Looking forward, the sales revenue of water electrolysis hydrogen production equipment in China is expected to increase from RMB6.13 billion in 2024 to RMB64.24 billion in 2028, with a CAGR of 79.9% during the period.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment

Sales Revenue of Water Electrolysis Hydrogen Production Equipment (Global and China), 2021-2028E

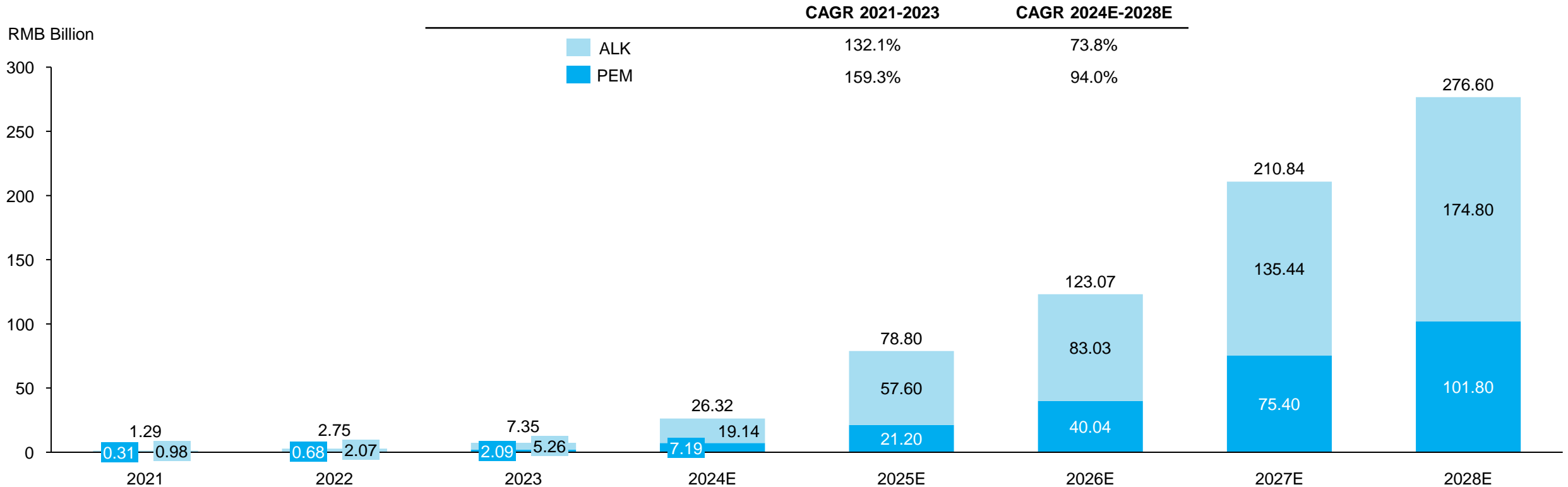




# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology

Sales Revenue of Water Electrolysis Hydrogen Production Equipment by Technology (Global), 2021-2028E

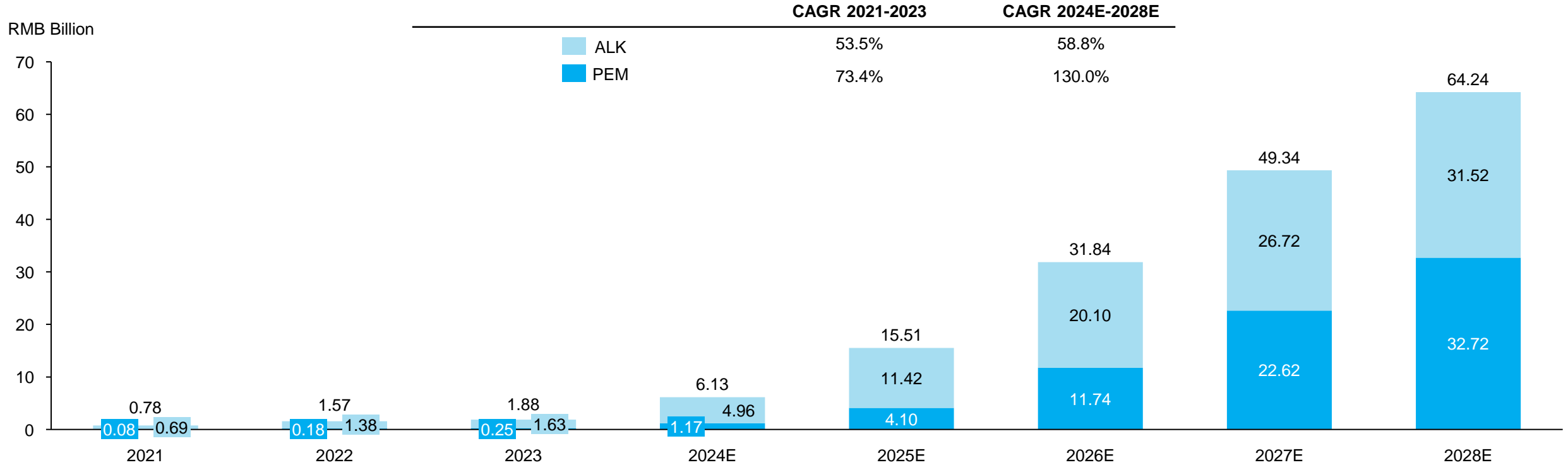


• The global market size of ALK water electrolysis hydrogen production equipment by sales revenue experienced a massive growth, expanding from RMB0.98 billion in 2021 to RMB5.26 billion in 2023, with a CAGR of 132.1% over the period. This momentum is expected to continue, with the market size further increasing from RMB19.14 billion in 2024 to RMB174.80 billion in 2028, representing a CAGR of 73.8% during the period. The market size of global PEM water electrolysis hydrogen production equipment by sales revenue increased from RMB0.31 billion in 2021 to RMB2.09 billion in 2023, with a CAGR of 159.3% over the period. With the development of PEM water electrolysis hydrogen production technology, it is expected that the market size of global PEM water electrolysis hydrogen production equipment by sales revenue will increase from RMB7.19 billion in 2024 to RMB101.80 billion in 2028, with a CAGR of 94.0%.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Size of Newly Installed Capacity of the Water Electrolysis Hydrogen Production Equipment by Technology

Sales Revenue of Water Electrolysis Hydrogen Production Equipment by Technology (China), 2021-2028E



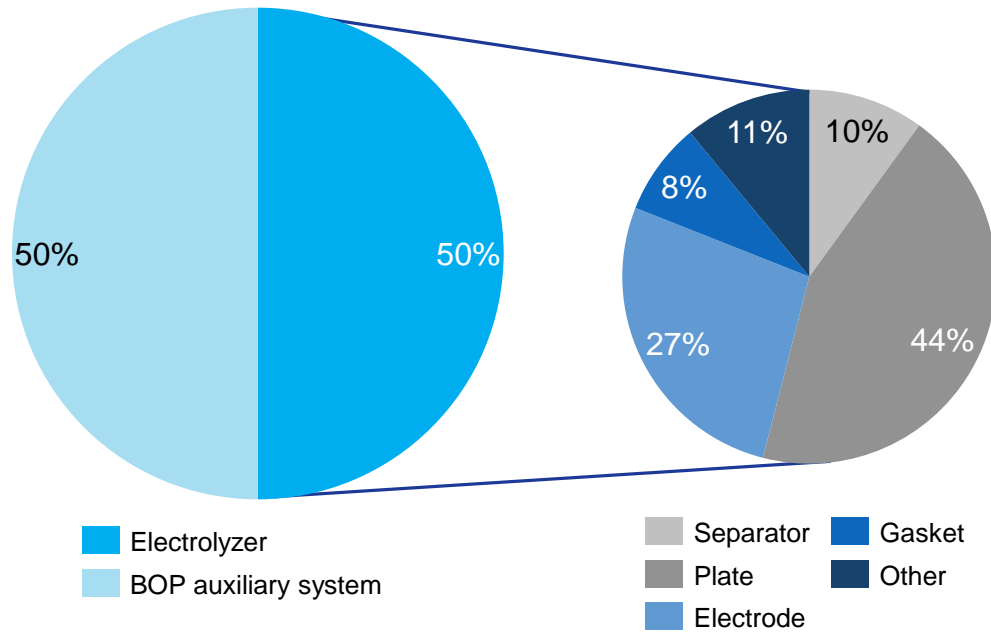
• The market size of China's ALK water electrolysis hydrogen production equipment by sales revenue witnessed a significant surge, increasing from RMB0.69 billion in 2021 to RMB1.63 billion in 2023, representing a CAGR of 53.5% over the period. Looking ahead, the China's ALK water electrolysis hydrogen production equipment market is expected to follow a similar trajectory, with its market size by sales revenue growing from RMB4.96 billion in 2024 to RMB31.52 billion by 2028, representing a CAGR of 58.8% during the period. Meanwhile, China's sales revenue of PEM water electrolysis hydrogen production equipment also witnessed an impressive growth, ballooning from RMB0.08 billion in 2021 to RMB0.25 billion in 2023, with a CAGR of 73.4% over the period. This momentum is predicted to continue, with the market size projected to increase from RMB1.17 billion in 2024 to RMB32.72 billion in 2028, representing a CAGR of 130.0% during the period.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Cost Structure Analysis

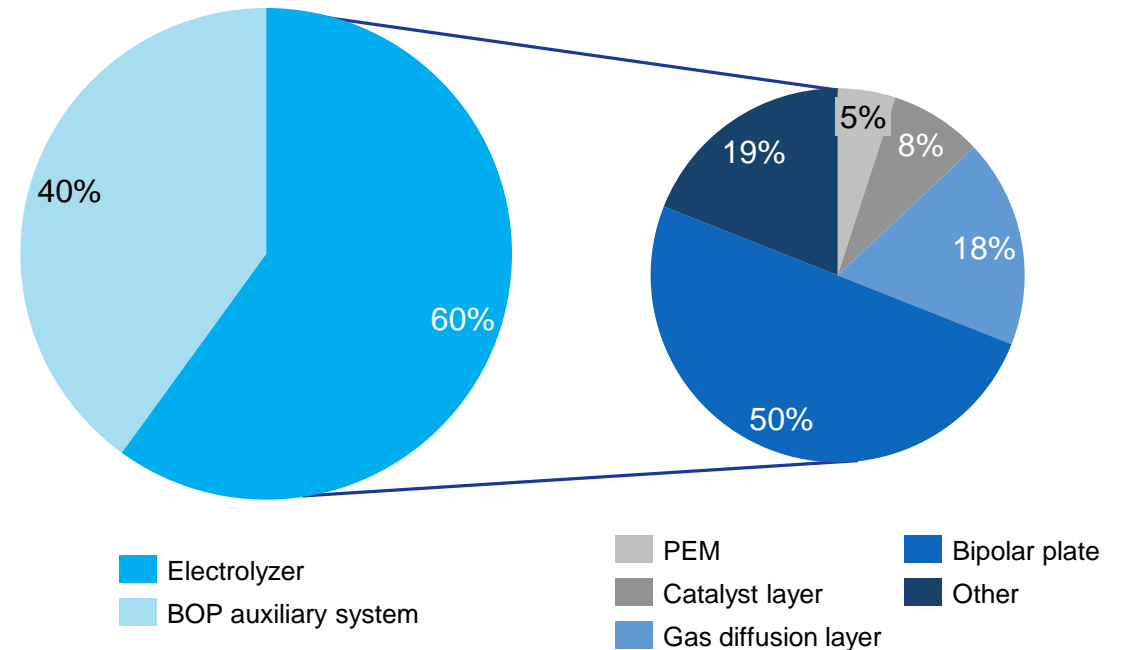
### Cost Structure of ALK and PEM Water Electrolysis Hydrogen Production Equipment (China), 2023

#### Alkaline Water Electrolysis



In 2023, the cost of ALK water electrolysis hydrogen production equipment is divided equally between the electrolyzer and the BOP(Balance of plant) auxiliary system in China. The cost of the alkaline electrolyzer in an ALK water electrolysis hydrogen production equipment can be further broken down as follows: plates accounted for 44%, electrode accounted for 27%, and the remaining components accounted for 29% of the total cost in 2023 in China. The overall cost of ALK water electrolysis hydrogen production equipment varies depending on factors such as equipment size, capacity, and raw material prices. Compared to other hydrogen production methods, ALK water electrolysis technology offers a competitive cost, particularly for large-scale installations.

#### Proton Exchange Membrane Water Electrolysis



In 2023, the cost structure of PEM water electrolysis hydrogen production equipment is primarily divided into the electrolyzer and BOP (Balance of Plant) auxiliary system, with the former accounting for 60% and the latter making up 40%. Upon further dissection of the electrolysis cost, the cost of the electrolyzer in a PEM water electrolysis hydrogen production equipment can be further broken down as follows: bipolar plates accounted for 50%, gas diffusion layer accounted for 18%, and the remaining components accounted for 32% of the total cost in 2023 in China.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Market Drivers and Developing Trends for Water Electrolysis Hydrogen Production Equipment

### Favourable regulatory environment around the globe

Hydrogen energy plays a pivotal role in the global transition towards sustainable energy systems. Energy independence and security are becoming key focus for governments around the world, which drives the growth of the water electrolysis hydrogen production equipment industry. This strategic focus aims to reduce reliance on traditional fossil fuels, bolster national energy security and combat climate change by embracing low-carbon energy. Through a series of policies, governments are fostering technological innovation, cost reduction and capacity scaling-up of water electrolysis hydrogen production equipment.

### Continuous development of renewable energy

The continuous decline in the cost of using renewable energy for electricity generation is expected to further reduce the cost of producing water electrolysis hydrogen production equipment, thereby enhancing its economic advantages. Moreover, power to gas (“PTG”) emerges as an ideal solution to address energy consumption and grid stability concerns. PTG involves converting excess electricity into hydrogen through water electrolysis hydrogen production technology, which is subsequently stored in hydrogen storage containers such as liquid hydrogen tankers for future use across broader geographical areas. As the core component of the PTG solution, water electrolysis hydrogen production equipment plays a pivotal role in enhancing the efficient utilization of clean energy.

### Combination of ALK and PEM water electrolysis technologies

The combination of ALK and PEM water electrolysis hydrogen production technologies has strengthened the wind-solar coupling, improved efficiency of hydrogen production and reduced the difficulty of grid configuration and control in off-grid scenarios. In the future, there will be more projects of ALK and PEM combined water electrolysis hydrogen production.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Entry Barriers of the Water Electrolysis Hydrogen Production Equipment Industry

1

### Technological Capabilities Barrier

- Water electrolysis hydrogen production equipment is a technological intensive industry that requires enterprises to possess advanced electrochemical technology and engineering design capabilities. Continuous innovation in technology and production process in improving electrolysis efficiency, reducing energy consumption and extending service life of electrolyzer is crucial for enterprises to enter and maintain competitive in the industry.

2

### Production Capabilities Barrier

- Enterprises in water electrolysis hydrogen production equipment industry need to invest significant capital in the construction of large-scale facilities and other supporting infrastructure and personnel. Meanwhile, these companies need to build a supply chain system to ensure the stable production of water electrolysis hydrogen production equipment.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Price Analysis of the Water Electrolysis Hydrogen Production Equipment Industry in China

- The price of water electrolysis hydrogen production equipment in China has been on a downward trend in recent years, driven by continuous technological breakthroughs, domestication of related core components as well as decreasing costs of renewable energy. As technological innovation continues, domestic manufacturing capabilities expand and the large-scale development of renewable energy production, the price of water electrolysis hydrogen production equipment in China is expected to continue its downward trajectory in the future, driving widespread adoption and contributing to the transition towards sustainable energy systems.

# Overview of the Water Electrolysis Hydrogen Production Equipment Industry

## Competitive Landscape

- There were over 30 major players in China's ALK water electrolysis hydrogen production equipment industry in 2023. These companies are vigorously involved in intensive R&D activities, aiming to increase the production capacity of hydrogen by ALK water electrolysis hydrogen production equipment during peak hours while concurrently reducing equipment costs. Currently, the ALK market is still considered to be in its early stages of development. In 2023, the top five ALK water electrolysis equipment providers accounted for over 50% of the market in terms of sales revenue. In 2023, there were over 15 distinguished companies specializing in PEM water electrolysis technology. However, the PEM market is in its very nascent phase of commercialization in China with each company possessing a considerably small scale of business. Therefore, the reliable market share data for PEM companies is currently unavailable.
- Currently, technology and value chain of the ALK water electrolysis hydrogen production equipment market in China are relatively mature. Meanwhile, PEM water electrolysis hydrogen equipment offers the advantage of rapid response time. The convergence of these two technologies may unlock a plethora of opportunities and lead innovative advancements in the hydrogen energy industry. We are one of a few leading companies in China that simultaneously have the manufacturing capability of these two types of water electrolysis hydrogen production equipment, and possess the ability to penetrate a broader spectrum of markets and dynamically choose between ALK and PEM technologies to explore the better balance between cost and efficiency.



# Agenda

- 1 Overview of the Hydrogen Energy Industry
- 2 Overview of the Vehicle-mounted High-pressure Hydrogen Supply System Industry
- 3 Overview of Core Equipment for Hydrogen Refueling Station Industry
- 4 Overview of Core Equipment for Liquid Hydrogen Industry
- 5 Overview of the Water Electrolysis Hydrogen Production Equipment Industry
- 6 **Appendix**



# Appendix

## Supporting Statements

- The hydrogen energy core equipment industry in China is still in the early stage of development, characterized by changing technologies, evolving government regulations and industry standards and changing market demands.
- Guofu is a leading integrated solutions provider of hydrogen energy equipment in China, specializing in developing and manufacturing hydrogen energy core equipment used in the entire industrial value chain of hydrogen energy.
- Carbon fiber faced supply constraints due to limited domestic production in China and foreign export controls in the past several years, leading to a price surge in 2021.
- The hydrogen energy core equipment industry evolves rapidly and is subject to rapid technological changes and developments.
- Guofu has achieved a leading position in vehicle-mount high-pressure hydrogen supply systems and related products and equipment for hydrogen refueling stations and related products in the hydrogen energy core equipment industry in China.
- Guofu also made various key breakthroughs in the production, storage and transportation of liquid hydrogen, maintaining our leading position in the progress of civilian use of liquid hydrogen in China.
- Guofu is a leading integrated solutions provider of hydrogen energy core equipment with respect to the following products:
  - ✓ It ranked first in terms of sales volume of vehicle-mounted high-pressure hydrogen supply systems in China in 2023, with a market share of 30.4%, and first in terms of sales volume of vehicle-mounted high-pressure hydrogen storage cylinders in China in 2023, with a market share of 29.4%. Furthermore, from 2019 to 2023, we ranked first in terms of sales volume of vehicle-mounted high-pressure hydrogen supply systems for five consecutive years in China, with a market share of over 30.0% each year.
  - ✓ It ranked first in terms of the number of hydrogen refueling stations built in China by 2023 where the equipment we assembled was used in the construction of such hydrogen refueling stations, with a market share of 25.7%. Additionally, we ranked first in terms of market share of the equipment for hydrogen refueling stations in China, which has remained above 25.0% for five consecutive years from 2019 to 2023. The 2022 Beijing Winter Olympics was the first large-scale application of 70MPa hydrogen refueling stations in China.
  - ✓ It was the first company to develop the technologies and have the capability to manufacture hydrogen liquefaction equipment for large-scale civilian use in China. Before 2023, the total liquid hydrogen production capacity of China remained relatively low at approximately five to eight tons per day. Guofu has successfully delivered China's first large-scale hydrogen liquefaction equipment civilian use with the production capacity of 10 tons per day, which was the first 10-ton level hydrogen liquefaction equipment in China and also the equipment with the largest production capacity in China.
  - ✓ There are only a few leading companies in China that simultaneously possess the ALK and PEM technologies for water electrolysis hydrogen production equipment. Guofu is the one of a few companies who are capable of (i) penetrating a broader spectrum of markets; (ii) dynamically choosing between ALK and PEM technologies to cater to customer demand; and (iii) realizing the cost effectiveness and efficiency of hydrogen production.
- Hydrogen energy is one of the important catalysts for the global energy transformation and development, especially with the exception that the introduction and growth of green hydrogen produced with renewable energy will change the global energy structure and contribute to new growth opportunities for sustainable economic development.

# Appendix

## Supporting Statements

- In recent years, the relevant government authorities of China, such as NDRC, MIIT, MOF, MOST and SAC, have issued a number of favorable national-level policies to support the development of hydrogen energy industry. In addition, a series of national-level policies relating to the energy plan, consumption plan and transportation plan also contributed to the development of China's hydrogen energy industry. The establishment of demonstrative city clusters, including Beijing, Shanghai, Guangdong, Hebei and Henan, further promoted the development of hydrogen fuel cell vehicles, thereby providing growth opportunities for the industry of hydrogen energy core equipment.
- Vehicle-mounted high-pressure hydrogen supply system is the energy storage unit of a hydrogen fuel cell vehicle. The system and its related products, such as hydrogen storage cylinders, are the key sub-system and components of hydrogen fuel cell vehicle.
- Expanding the geographic coverage of hydrogen refueling stations and the efficiency of the supply of hydrogen will promote the wider use of hydrogen fuel cell vehicles.
- In view of the requirements of the “Carbon Peaking and Carbon Neutrality” objective, it is expected that using renewable energy sources to produce hydrogen through water electrolysis technology, will become one of the mainstream approaches used for hydrogen production in the future as it produces zero carbon emissions during production activities.
- Guofu has maintained the largest market share of vehicle-mounted high-pressure hydrogen supply systems in China in terms of sales volume and the largest market share of hydrogen refueling stations in terms of the number of hydrogen refueling stations built in China that were equipped with our equipment for five consecutive years from 2019 to 2023.
- In the field of liquid hydrogen, Guofu made a number of key breakthroughs and guided the pace of R&D of domestic liquid hydrogen core technologies and key equipment in China.
- Guofu maintained our marketing leading positions with respect to the following products:
  - ✓ “Qinglong No. 1 (氢龍一號)” is the first high-power hydrogen energy shunting locomotive in China.
  - ✓ Guofu's equipment for hydrogen refueling stations was used in a number of first demonstration projects in China, including: (i) the first integrated hydrogen production and refueling station; (ii) the first oil-hydrogen hybrid refueling station; and (iii) the first oil, gas and hydrogen integrated energy station.
  - ✓ Guofu is one of the pioneers in the localization, commercialization and large-scale development of the equipment for production, storage and transportation of liquid hydrogen in China. In terms of hydrogen liquefaction, In terms of hydrogen liquefaction, we are the first manufacturer in China that adopted the hydrogen expansion refrigeration process for liquefaction of hydrogen for civilian use.
  - ✓ Guofu was the first company to pass the evaluation of liquid hydrogen enterprise standards conducted by China Standardization Committee of Boilers and Pressure Vessels. It has participated in the compilation of the first group standards for storage and transportation vessels of liquid hydrogen. It has successfully developed, manufactured and delivered the first 200 m3 liquid hydrogen container used in a large-scale civilian use liquid hydrogen plant in China. Meanwhile, it developed and manufactured the first liquid hydrogen tank sample for civilian use.
- Guofu's technologies for vehicle-mounted hydrogen supply systems and hydrogen storage cylinders have achieved the international advanced levels.
- China's hydrogen energy industry still relies on the import of certain key equipment and raw materials, which led to relatively high production costs for domestic manufacturers of hydrogen energy core equipment.
- Green hydrogen, which is produced from renewable energy through water electrolysis, will become increasingly favored by the market in the future.
- The development of the global hydrogen energy industry is still in the initial stage of commercialization.
- Transportation sector is one of the major sectors in China that used hydrogen energy in various applications.
- Vehicle-mounted high-pressure hydrogen storage cylinder is currently the most widely used gaseous hydrogen storage method.

# Appendix

## Supporting Statements

- Hydrogen liquefaction process mainly involves having (i) hydrogen go into the pre-cooled heat exchanger and flow through the low-temperature purifier to achieve hydrogen cooling and purification; (ii) hydrogen flow through the ortho-para-hydrogen converter, and part of the ortho-hydrogen is converted into para-hydrogen; (iii) hydrogen flow into the high vacuum cold box, intercepted and liquefied after exchanging heat with the cold energy provided by the expander, and is stored in the liquid hydrogen storage tanks; (iv) liquid hydrogen enters the mobile liquid hydrogen tanks through the filling system for transport; and (v) evaporated gas goes back to the liquefaction cold box for secondary liquefaction.
- It is expected that using renewable energy through water electrolysis will become one of the mainstream approaches used for hydrogen production in the future. Water electrolysis hydrogen production involves an electrochemical process that splits water into hydrogen and oxygen by employing electricity. This reaction occurs within a device known as an electrolyzer.
- Germany is the largest economy in Europe in 2023. The European hydrogen energy market is characterized by high customer demand and favorable policy environment, resulting in substantial business opportunities for hydrogen energy projects.
- Singapore is a leading global energy trading center. As a key pathway of decarbonization, developing hydrogen energy is Singapore's national strategy.
- The UAE is committed to becoming a global hydrogen energy trade and technology development center. It has raised the development of hydrogen energy as a national development strategy. The local hydrogen market in the UAE has great potential and its business extends to the neighboring markets in the Middle East.
- Brazil has abundant renewable energy resources and strong industrial base. It is expected to become a major producer and exporter of hydrogen energy in the future and a major global supplier of green hydrogen.
- The Netherlands is a major hydrogen producing country in Europe and has a relatively well-developed hydrogen energy ecosystem.
- The Indian government highly encourages the development of the hydrogen energy industry. India is committed to becoming a hydrogen energy production and export center in South Asia.
- The popularity of Type-IV cylinders has been gaining traction in China in recent years.
- Historically, the global carbon fiber industry was dominated by foreign manufacturers, and Chinese manufacturers primarily relied on imports of such raw material.
- Hydrogen energy industry is still in its early developing stage, and is gradually shifting from the policy-driven to market-driven.
- Green hydrogen, which is produced through water electrolysis powered by renewable energy sources like solar and wind, represents a pivotal advancement in sustainable energy.
- Governments globally are actively pursuing the “carbon neutral” goal and have implemented policies to promote clean energy development. Green hydrogen has become a pivotal strategy in achieving carbon neutrality, facilitating the transition to cleaner energy sources, enhancing energy security, and modernizing traditional industries.

# Appendix

## Supporting Statements

- We are a leading integrated solutions provider of hydrogen energy equipment in China, specializing in developing and manufacturing hydrogen energy core equipment used in the entire industrial value chain of hydrogen energy, which consists of its production, storage, transportation, refueling and use.
- Guofu was the first company in China to develop the technology and have the capability to manufacture hydrogen liquefaction equipment for large-scale industrial production. In addition, it developed and manufactured the first liquid hydrogen tank sample for civilian use in China.
- Guofu is one of a few leading companies in China that simultaneously have the manufacturing capability of these two types of water electrolysis hydrogen production equipment, and possess the ability to penetrate a broader spectrum of markets and dynamically choose between ALK and PEM technologies to explore the better balance between cost and efficiency.
- The market for hydrogen energy core equipment is characterized by ongoing technological development, evolving industry and national standards, shifting customer demand, increasing product diversity, frequent introductions of new products and enhancements of existing products towards commercialization. The overall competitiveness and market appeal of our products are affected by the adoption of new technologies and introduction of new products by our competitors, establishment of new industry and national standards, changes in customer demand and preferences and/or changes in government policies and regulations.
- Although Guofu held several leading positions in China's hydrogen energy core equipment industry with respect to certain products, such as vehicle-mounted high-pressure hydrogen storage systems and equipment for hydrogen refueling stations, it faces intense competition in China and globally from other market participants.
- As a player in hydrogen energy industry, Guofu's business development in this industry is highly driven by policies, particularly government awards, subsidies or government sponsored projects that directly promote market demand for hydrogen energy.
- Nonetheless, as the regulatory framework and government policies in the PRC for hydrogen energy industry, hydrogen energy core equipment industry and hydrogen fuel cell vehicle industry are relatively new and still evolving.
- The customer demands for equipment for hydrogen liquefaction, the storage and transportation of liquid hydrogen, and water electrolysis hydrogen production equipment do not have material seasonality.
- Vehicle-mounted high-pressure hydrogen supply systems with larger hydrogen storage capacity became more popular in the market since hydrogen fuel cell vehicle manufacturers focused on improving the long distance capacity and power (功率) of their hydrogen fuel cell vehicles.
- There was a slow-down in the growth of new hydrogen refueling stations built in 2022 in China.
- There was an increasing competition between the players in the core equipment for hydrogen refueling station industry as a result of the decreasing customer demand in 2022 in China.
- There was a more abundant supply of carbon fiber in 2023 in China.
- There was a shortage of carbon fiber in 2022 in China. In 2023, carbon fiber became more readily available in China.
- Type-IV cylinders are more widely applied in hydrogen fuel cell vehicles in overseas markets compared to that in China.
- Considering the development of China's hydrogen energy industry has not matured, government awards and incentives and the pattern of seasonal fluctuations in customer demand thereof are expected to continue in the foreseeable future.



# Appendix

## Supporting Statements

- Guofu is one of the domestic leaders in the development of vertical and horizontal liquid hydrogen storage tanks, liquid hydrogen containers and large-capacity liquid hydrogen storage cylinders.
- Vehicle-mounted high-pressure hydrogen storage cylinders manufactured in China have relatively lower material costs and manufacturing costs compared with those imported from overseas suppliers. In addition, imported vehicle-mounted high-pressure hydrogen storage cylinders are subject to on-site testing by an independent inspection agency and verification of satisfactory test results before they can enter into China's market.
- Civilian use in liquid hydrogen industry has a large growth potential.
- As advised by Frost & Sullivan, (a) [as at the date hereof], there are only two hydrogen liquefaction equipment projects for civilian use which have concluded sales orders, one of which is the industrial-scale hydrogen liquefaction equipment for civilian use with the production capacity of 10 tons per day provided by the Company to Qilu Hydrogen, and the other one relates to hydrogen liquefaction equipment for civilian use with the production capacity of 1.5 ton per day; and (b) the contract price for the hydrogen liquefaction equipment for civilian use with the production capacity of 1.5 ton per day is around RMB40 million.
- China's hydrogen energy core equipment industry is still in its early stage of development.
- The PRC government has continued to introduce supportive policies for hydrogen energy industry and fuel cell vehicle industry in recent years. This indicates that the end market for hydrogen energy core equipment is expected to have a relatively large growth potential.
- Shanghai Refire Group has the leading position and good reputation of in the hydrogen fuel cell system market in China.
- SHPT Group is one of the pioneers in the R&D of hydrogen fuel cell technology in China and has a good reputation in the industry.
- Sino-Synergy Group is a leading enterprise in the hydrogen fuel cell industry market in China, with large sales volume in the industry for consecutive years since 2018.
- China FAW Group is one of the leading companies in the heavy truck automobile industry in China.
- The prolonged settlement of trade receivables of vehicle-mounted high-pressure system companies with their customers was partly due to the early-stage development of the industry and the influence of awards and subsidies policies.
- Prior to the announcement of the policy of demonstration city clusters, complete vehicle manufacturers were responsible for the subsidy application during the promotion stage of hydrogen fuel cell vehicles.
- Vehicle manufacturers are one of the major types of customers of vehicle-mounted high-pressure hydrogen supply system manufacturers, whose businesses are subject to the seasonality of China's hydrogen fuel cell vehicle industry.

# Appendix

## Supporting Statements

- Fostering the advancement of hydrogen production from renewable sources is a pivotal strategy in driving the decarbonization efforts across various industries, primarily because utilizing renewable energy for water electrolysis presents substantial advantages in curbing carbon emissions compared to traditional hydrogen production methods that rely on fossil fuels. Therefore, the Chinese government has implemented a series of supportive policies, including incentives for breakthroughs in core technologies for water electrolysis hydrogen production and facilitating demonstration applications of hydrogen production from renewable energy. Such supportive measures are poised to promote the increasing demand for hydrogen produced from renewable energy, thus yielding substantial benefits for equipment manufacturers of the water electrolysis hydrogen production industry. The proportion of green hydrogen in China is expected to surge from less than 5% in 2023 to approximately 20% of the total hydrogen production volume by 2030. Consequently, the market size of China's water electrolysis hydrogen production equipment industry in terms of revenue is projected to sustain its upward trajectory in the forthcoming years, reaching RMB64.2 billion in 2028, representing a CAGR of 79.9% from 2024 to 2028.
- Revenue of hydrogen-related products, primarily consisting of sales of products for equipment in hydrogen refueling station, accounted for approximately 15% of the total revenue of Houpu Clean Energy Co., Ltd. in 2023.
- Considering the preliminary stage of China's hydrogen energy industry, we remain at a loss-making position during the Track Record Period. According to Frost & Sullivan, the hydrogen energy related industries are still in the developing stage, factors such as the relatively high costs, immature technologies, limited market demand, lack of economies of scale and high costs affect the profitability of market players in the industry. Accordingly, many market players along the value chain (e.g., hydrogen fuel cell system manufacturers and hydrogen energy equipment manufacturers) are still loss-making. The hydrogen energy industry in China remains in the developmental stage primarily due to several interrelated challenges. For instance, the core technologies related to hydrogen production, storage and use are still relatively new and immature, leading to higher production costs. On the demand side, the market demand of hydrogen energy is still limited. Without sufficient market adoption, achieving economies of scale would be difficult, further raising the costs of hydrogen energy. As a result, many market players along the value chain, including hydrogen fuel cell system manufacturers and hydrogen energy equipment manufacturers, continue to operate at a loss.



# 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 Global and China Hydrogen Energy Core Equipment 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