

Accelerating the growth of natural gas power generation in China towards a zero-carbon future

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Addressing climate change must be an urgent global priority requiring international action, national commitments, and consistent policy and regulatory frameworks. GE believes that accelerated and strategic deployment of renewables and gas power can change the trajectory for climate change, enabling substantive reductions in emissions quickly, while in parallel continuing to advance the technologies for low or near zero-carbon power generation required for the world to achieve its collective goals for a net zero world.

The development of the power industry in the Guangdong-Hong Kong-Macao Greater Bay Area of China (GBA) has achieved remarkable results, and it is a great regional reference for the rest of China.

The interconnection level, power supply capacity, quality, and reliability of the regional power grids are some of the best in the nation. The power supply structure has been continuously optimized and the scale of natural gas power plants has increased rapidly.



Building a world that works

POWER INDUSTRY REFORM UNDER THE GOAL OF CARBON NEUTRALITY

China is a major power producer and consumer, and the first developing country to set a carbon neutrality target. With the goal of reaching peak CO₂ emissions in 2030 and carbon neutrality in 2060, China plans to construct 1,200 gigawatts (GW) of wind and photovoltaic power. China is accelerating the construction of a modern power system to achieve a rapid and in-depth transformation. Although thermal power still plays a dominant role in China's power generation mix, its growth in terms of installed capacity and generation is slowing, and its share of the overall mix is declining relative to renewables. Due to the intermittency of renewables, the grid requires both highly flexible and stable baseload power to ensure stability of the power grid.

In 2020, China's installed power generation capacity reached 2,200 GW, which is a year-on-year growth of 9.5%. Thermal power generation capacity reached 1,245 GW, or 57% of total capacity and year-on-year growth of 4.7%. Coal represented 1,079 GW of thermal installed capacity, or 49% of the total with 3.8% year-on-year growth. Gas power installed capacity was 98 GW, an increase of 8.6% year-on-year, and it made up 4.5% of total installed capacity.

DEVELOPMENT STATUS AND PROSPECTS FOR NATURAL GAS POWER GENERATION IN CHINA

CHINA'S NATURAL GAS POWER GENERATION IS IN A PERIOD OF RAPID DEVELOPMENT.

As one of the primary uses of natural gas in China, power generation is experiencing significant development opportunities. Since July 2014, the National Development and Reform Commission (NDRC) has successively issued a series of relevant policies to encourage and promote the development of natural gas power generation. In June 2017, the Opinions on Accelerating the Utilization of Natural Gas issued by the NDRC proposed to promote natural gas as a key part of China's modern clean energy system. Meanwhile, reform and development of the natural gas power generation industry are also advancing. During the 13th Five-year Plan period, China's natural gas power generation increased by 9.7% annually. As of June 2021 in China, the installed capacity of gas-fired power generation with an output greater than or equal to 6 MW reached 106 GW. With the large-scale development and utilization of China's natural gas resources, the national "West East Gas Pipeline Project", offshore natural gas development

and the introduction of foreign liquefied natural gas, supply is easing, and with the acceleration of market-oriented reform, the cost of gas power will gradually decline. On one hand, natural gas power generation will continue to replace coal power and support China's overall decarbonization* and environmental strategies. On the other hand, flexible and efficient distributed energy projects of natural gas will provide reliable power supply to areas such as industrial parks, logistics parks, tourism service areas, large commercial facilities, transportation hubs, schools, hospitals—where uninterrupted electricity is paramount. Furthermore, the country is encouraging the development of multi-energy complementary distributed energy projects combining natural gas with wind power, photovoltaic power generation, and other renewable energy.

*Decarbonization in this paper is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis.

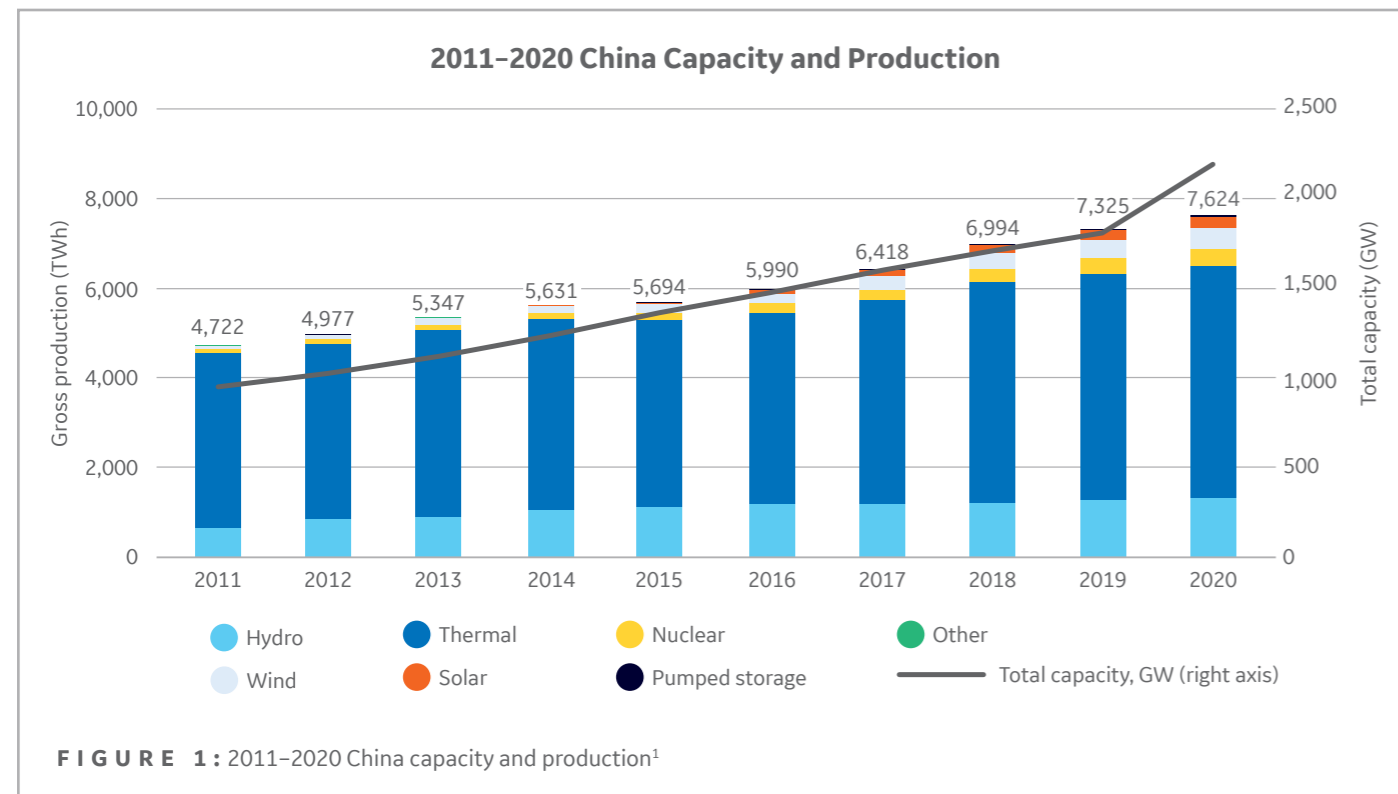


FIGURE 1: 2011-2020 China capacity and production¹

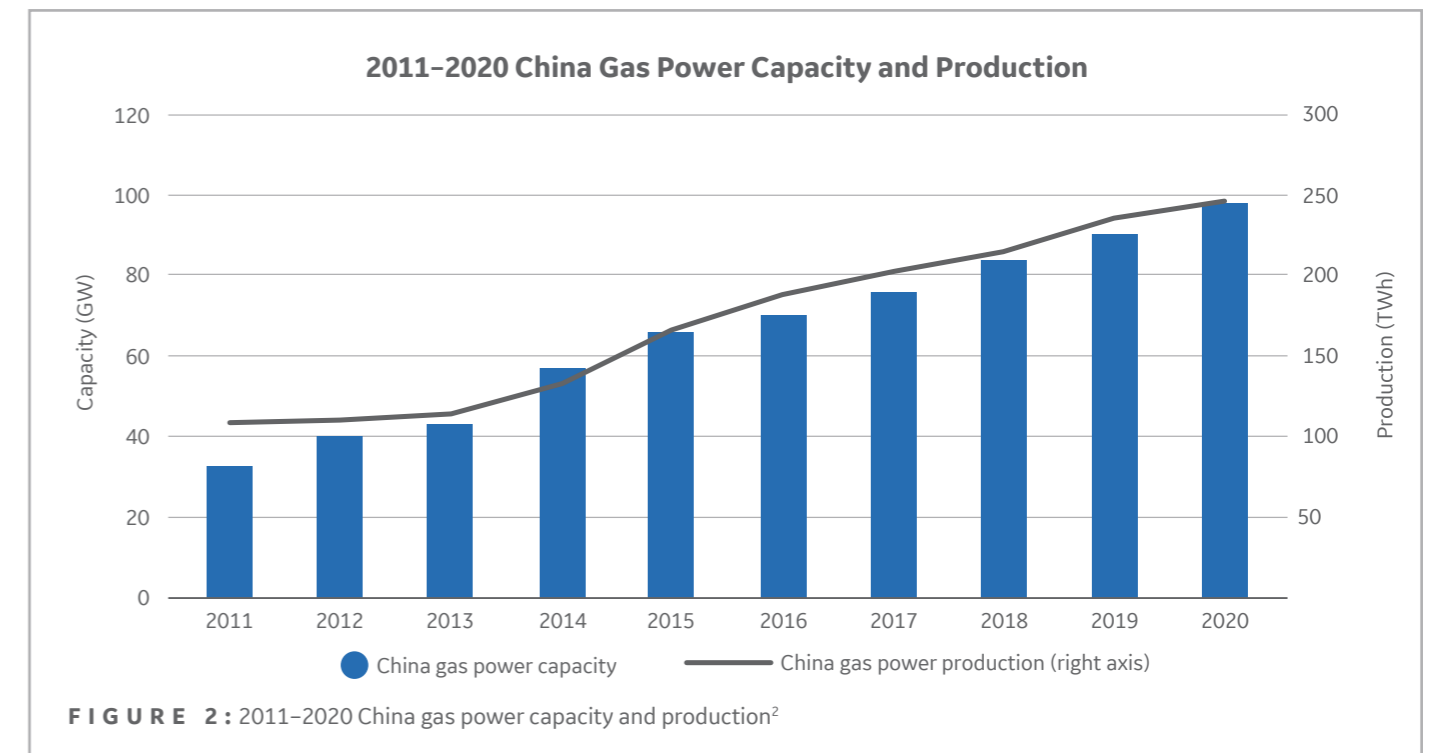


FIGURE 2: 2011-2020 China gas power capacity and production²

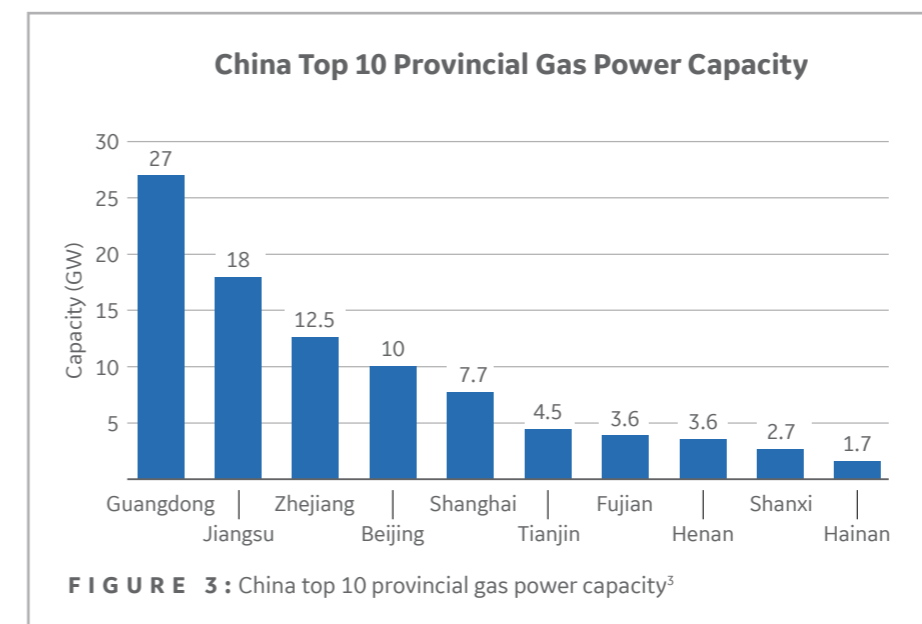


FIGURE 3: China top 10 provincial gas power capacity³

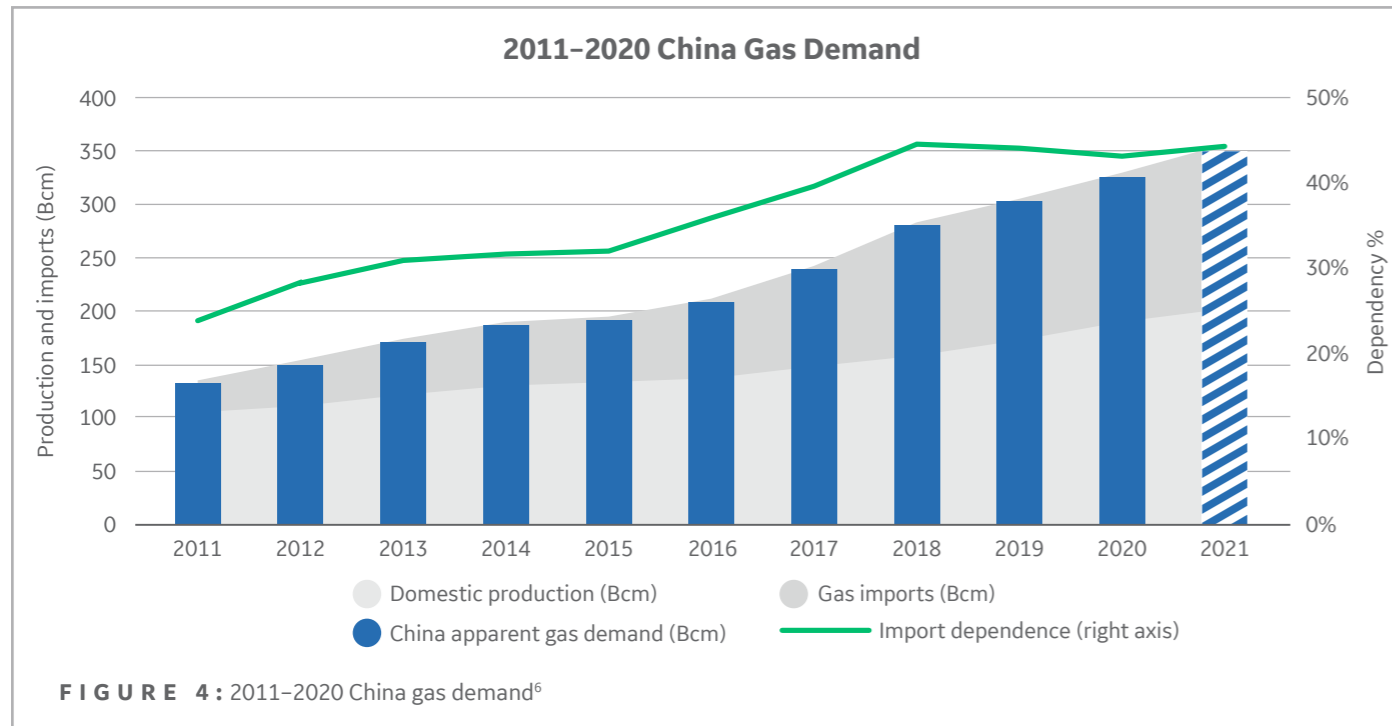


FIGURE 4: 2011–2020 China gas demand⁶

CHINA'S NATURAL GAS SUPPLY HAS ACHIEVED STABLE SUPPLY THROUGH MULTIPLE CHANNELS

The country continues to build a safe, reliable, flexible, and resilient natural gas industry and supply chain, and has actively participated in the international natural gas market. China's recoverable natural gas resources are 85.4x10¹²m³, ranking second in the world.⁴ During the 13th Five-year Plan period, China's natural gas supply increased more than 10 billion cubic meters (bcm), with the average annual growth rate exceeding 7.4%.⁵ According to the latest statistics of the International Energy Agency (IEA) in 2021, China's natural gas production ranks fourth in the world. During the 13th Five-year Plan period, China made efforts in exploration and production domestically and continued to increase the scale of imported natural gas including LNG in order to establish a stable foundation for gas power development.

THE 14TH FIVE-YEAR PLAN PERIOD WILL BE A STRATEGIC "WINDOW PERIOD" FOR THE DEVELOPMENT OF THE GAS POWER INDUSTRY

It is estimated that by 2025, China's installed capacity of gas power generation will exceed 150 GW, accounting for about 6% of the total installed power generation capacity. According to the "China Natural Gas Development Report (2021)" which was issued by the National Energy Administration, State Council and

Ministry of Natural Resources, natural gas consumption will reach 430–450 bcm in 2025, and 550–600 bcm in 2030. After that, natural gas consumption will grow steadily and sustainably, and stabilize around 2040. Compared with the development path of the natural gas industry in developed countries, the main driving force for consumption growth comes from power generation. At the beginning of 2021, the installed capacity of gas power generation in China exceeded 100 GW, accounting for 4.5% of the total installed capacity of power generation, far below the global average 23.4%.

Natural gas power generation is the lowest carbon emitting fossil fuel. At the same time, it has flexible operation and fast start-up characteristics. It can generate power for base load or for peaking operation. In addition, judging from the country's positioning and demand for gas power in building a new power system, gas power is not only an important component to replace coal power to reduce carbon emissions (as is the case with international experience), but also to support the flexibility and safety of the power grid after the increase in the proportion of renewable energy.

For now, the proportion of flexible power supply is low in China. Flexible and dispatchable power sources such as pumped storage and gas-fired power generation account for only 6% of the total,

so, there is an urgent need for gas power with high efficiency, low emissions, and strong flexibility.

REFORM IS ADVANCING THE SUSTAINABLE DEVELOPMENT OF THE GAS POWER INDUSTRY

Both upstream and downstream industries involved in the gas power industry are in the process of advancing market-oriented reform. Only by continuously advancing the reform of upstream natural gas and downstream power markets, establishing a fair, open, transparent, and orderly market environment, and improving the market-oriented mechanism of gas power linkage and power ancillary services can the gas power industry achieve sustainable development. In addition, the continuous maturity and growth of a carbon trading market will also provide a powerful external development environment for the development of the gas power industry. All parties in the upstream, midstream, and downstream segments of the natural gas industry should strengthen cooperation, develop collaboratively, build a good industrial ecosystem, and jointly promote the health and stability of the industry. The implementation of vertical integration in the natural gas industry can improve the efficiency and competitiveness of the entire industry chain, thereby realizing coordinated and sustainable development of the industry and contributing to the coordinated emissions reductions of upstream and downstream.

EXPLORATION AND APPLICATION OF GAS POWER ZERO CARBON TECHNOLOGY

Zero carbon emission technology is an important technical choice for the future development of natural gas power generation. The breakthrough of zero carbon technology can create new opportunities for the development of the natural gas power generation industry. Carbon capture, utilization, and storage (CCUS) technology can either permanently store CO₂ or make it available for use in various fields. In recent years, hydrogen as a fuel has become a research hotspot. Hydrogen can be blended with natural gas to improve the combustion efficiency of gas turbines while helping to protect the environment. It is one of the key paths for gas power to achieve near-zero carbon emissions in the future. Gas turbines have been operating on high hydrogen/low heating value gases for decades. At present, the most advanced HA-class gas turbine can burn natural gas mixed with up to 50% hydrogen by volume, and it is expected to achieve 100% hydrogen combustion capability in approximately the next decade.

Based on the above inherent characteristics of hydrogen, the DLN2.6e combustor in GE's H-class gas turbine uses micromixer premixed combustion technology, which was developed by GE and the United States Department of Energy in 2005. Figure 5 is a cross-sectional view of GE's DLN2.6e combustor. The gray and white tube bundle is the advanced premixer, and the red part is the shell of the premixer. The

nozzles for axial fuel staged combustion are distributed at the upper and lower parts of the integral part of the transition section of the combustion cylinder. The rear half of the integral part is connected with the inlet of the stage 1 nozzle. The compressor exhaust countercurrent surrounds the entire combustion chamber. The air countercurrent enters the burner end cover, and then goes into the premixing tube bundle, which is uniformly mixed with the fuel in the outer cavity of the tube bundle after passing through the micropore of the tube wall.

THIS DESIGN CAN SOLVE SOME PROBLEMS OF HYDROGEN FUEL

- Hydrogen fuel has wide flammability limits, and the maximum variation range of Wobbe index can be up to +/-15%. This will enable the same burner to burn both pure methane and pure hydrogen.
- High premixing efficiency. Compared with the previous combustors, the DLN2.6e adopts a small-size nozzle which can not only achieve sufficient premixing, but also support fast fuel speed. When the fuel speed is faster than the combustion speed, damaging flashback can be avoided.
- Strong NO_x emission control capability. The small-size nozzle is adopted for ensuring sufficient premixing. The burner is integrated with the transition section to reduce the retention time of high-temperature flue gas, and staged combustion is adopted to make the high flame temperature area more uniform, reducing NO_x emissions.

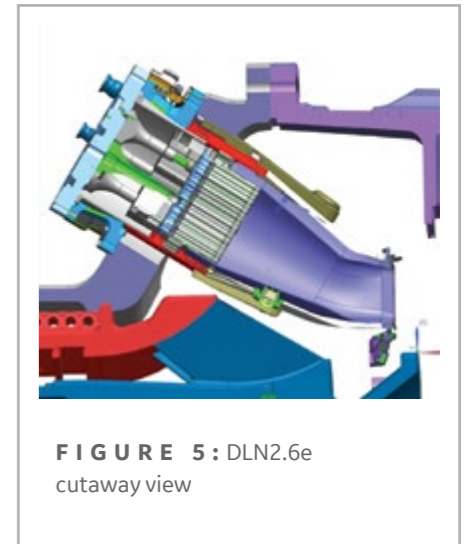


FIGURE 5: DLN2.6e cutaway view

In terms of hydrogen blended combustion, GE currently has more than 100 gas turbines operating for more than 8 million hours.



The development of the power industry in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) has achieved remarkable results. The interconnection level, power supply capacity, quality, and reliability of the regional power grids are leading in the country. The power supply structure has been continuously optimized and the scale of natural gas power plants has increased rapidly, accounting for about 29% of the total installed capacity of gas power in China. Guangdong Province also has the highest installed capacity of gas power in the country. The GBA is a great reference for the rest of China.

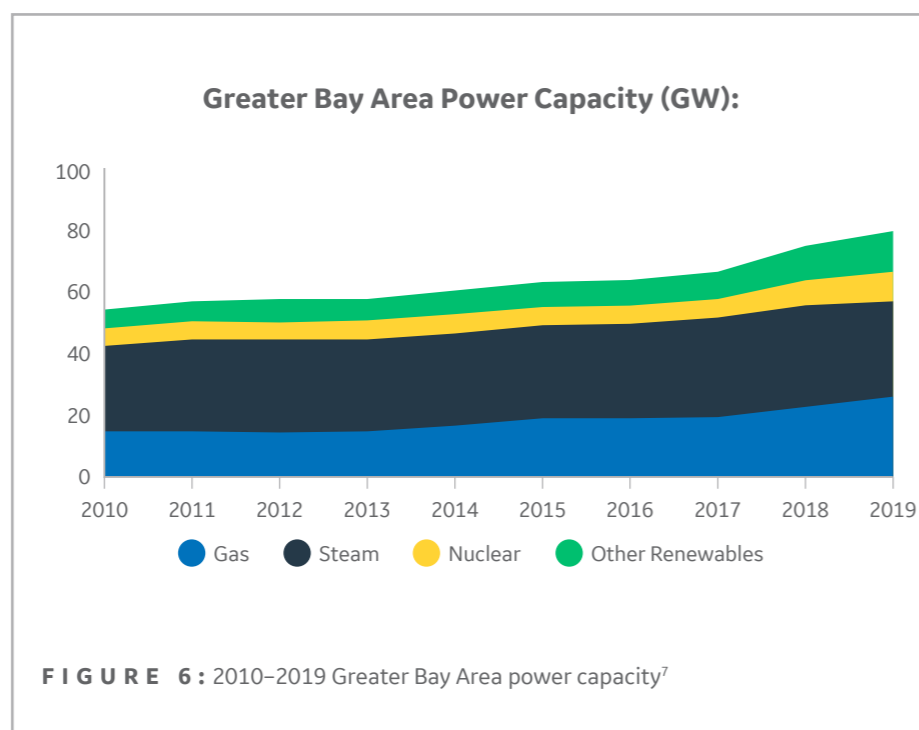


FIGURE 6: 2010–2019 Greater Bay Area power capacity⁷

Status of energy demand. In the medium and long term, the economy and industrial structure of the Greater Bay Area will be deeply transformed to low-carbon and zero-carbon. The positive economic impact of new industries, new business forms, and new business models will be obvious. The proportion of the service industry and high-end advanced manufacturing industries will rise, and enterprises with high energy consumption and high carbon footprints will gradually transfer outside the region, the contribution of greener technologies will increase, and energy efficiency will be significantly improved. The electrification level of the transportation industry, service industry and the residential sector will continue to increase and zero-carbon fuels such as hydrogen will become a new energy growth opportunity.

Decarbonized and environment protection status. In terms of environmental protection and carbon reduction, the proportion of non-fossil energy consumption in the GBA will gradually increase, and the proportion of electric energy in final energy consumption will steadily increase. It is estimated that the proportion of coal and non-fossil energy will be about 16% and 42%, respectively, by 2025 and will be further improved to 6% and 52% by 2035. The carbon emissions intensity will be decreased significantly, and total carbon emissions in the GBA are expected to peak around 2025.

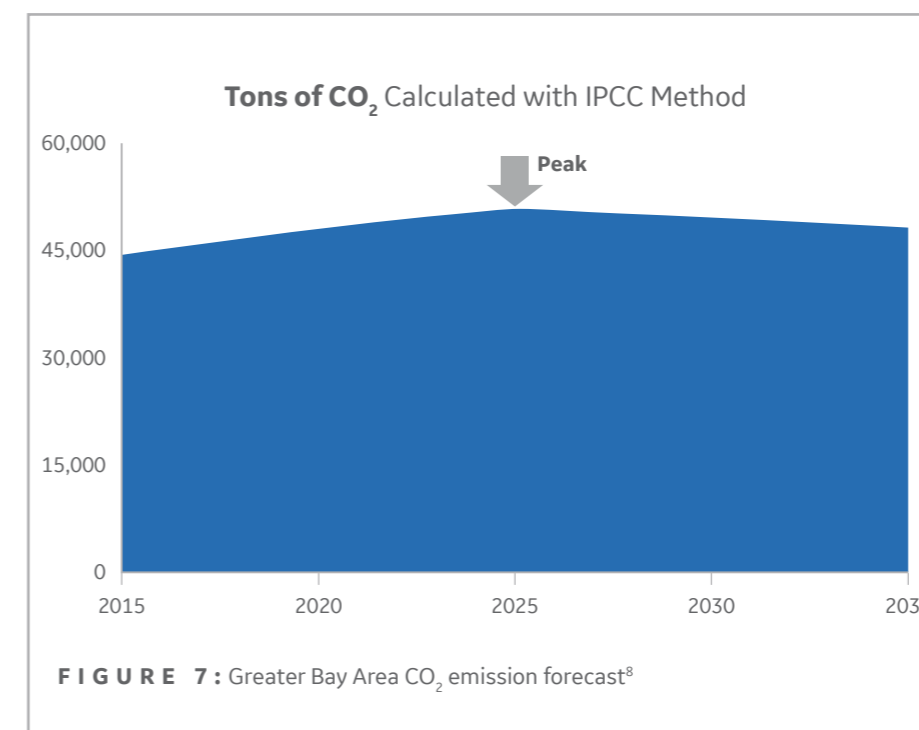


FIGURE 7: Greater Bay Area CO₂ emission forecast⁸

Power supply. The installed power generation capacity in the GBA will gradually increase, with the largest increase in the installed capacity of renewables and natural gas power generation. By 2025, the installed power capacity of the GBA will be close to 100 GW, of which gas power generation will account for about 46%; By 2035, it will reach 130 GW, of which installed capacity of gas power will reach more than 50 GW. Gas power's share of the total will drop to about 42% due to the significant increase in renewable energy installed capacity.

The overall policy orientation of future gas power development in the GBA.

As an important backbone of the power supply mix after the shutdown of coal power in the GBA, gas power will play an important role in balancing power supply with demand and ensuring the safety and stability of the grid in the GBA. Through coordinated layout with the provincial natural gas trunk pipeline network and LNG terminals, China will promote the construction of natural gas peak shaving power stations and carry out the preliminary work of gas power projects in combination with regional load growth and flexible peak shaving requirements. In key energy consuming areas and industrial parks, China will

actively develop natural gas distributed energy projects, promote regional combined cooling, heating, and power (CHP), reduce pressure on power grid transmission and power grid construction, and optimize and adjust the regional power supply structure and power grid operation stability.

The requirements of an intelligent power grid for the development of gas power in the future. With the continuous development of low-carbon power in the GBA, there is an urgent need for an intelligent power grid to comprehensively improve power supply reliability, power quality, and service level of the grid.

Development of gas power promoted by carbon trading and energy-consuming trading. In the future, the GBA will accelerate power market trading rules, accelerate the construction of a unified power market in the south, and establish a market platform for regional allocation of power resources. The improved power market will provide better guarantees and support for cleaner forms of power.

The policy on the price of gas power in the future. To promote a better development of gas power, Guangdong has released a series of policies including the Action Plan for Air Pollution Prevention

and Control in Guangdong Province (2014–2017) and the Implementation Plan for Fighting Air Pollution in the Guangdong Province (2018–2020). To address the price of electric power, it has issued the Notice of Guangdong Province Development and Reform Commission on the On-grid Electricity Price of Natural Gas Generating Units Exceeding the Limited Hours (YFGJGH [2021] No. 1007). The on-grid price of all types of units exceeding the limited annual utilization hours is uniformly 0.463 yuan per kWh. The on-grid price of natural gas power generation within the limited annual utilization hours is implemented for the power of all types of units, with about 0.3 yuan/kWh subsidized if the price is higher than coal power.

In addition, Guangdong Province has also issued policies on promoting the expanded utilization of natural gas and establishing and improving the production, supply, storage and marketing system of natural gas.

Security of future natural gas supply. The GBA lacks onshore natural gas resources and does not have natural gas production capacity. Natural gas is obtained mainly through international and domestic markets.

Considering the decision-making of the country and Guangdong Province to address the dual control constraints on energy consumption and vigorously promote carbon peaking and carbon neutrality, the future gas power development policy of the GBA will mainly focus on the following aspects: **first**, give full recognition to the peak shaving capability and dispatchability of large-scale and efficient gas power to meet the carbon peaking and carbon neutrality goals; **second**, promote the integrated development of gas power and renewable energy; **third**, ensure the safe and stable supply of natural gas and accelerate the construction of the natural gas pipeline network system in the GBA; and **fourth**, promote the linkage of gas prices and power prices, and ease the possible cost pressure of gas prices on natural gas power plants.

Natural gas power generation is an important component of realizing China's "carbon peaking and carbon neutrality" goals and an important support for the safety and reliability of the power grid.

DEVELOP

high-efficiency gas turbines according to local conditions to support increased deployment of gas power

STRENGTHEN

the integration of gas power and wind power, photovoltaics, hydrogen and other energy sources to achieve coordinated development of the gas power industry

ENSURE

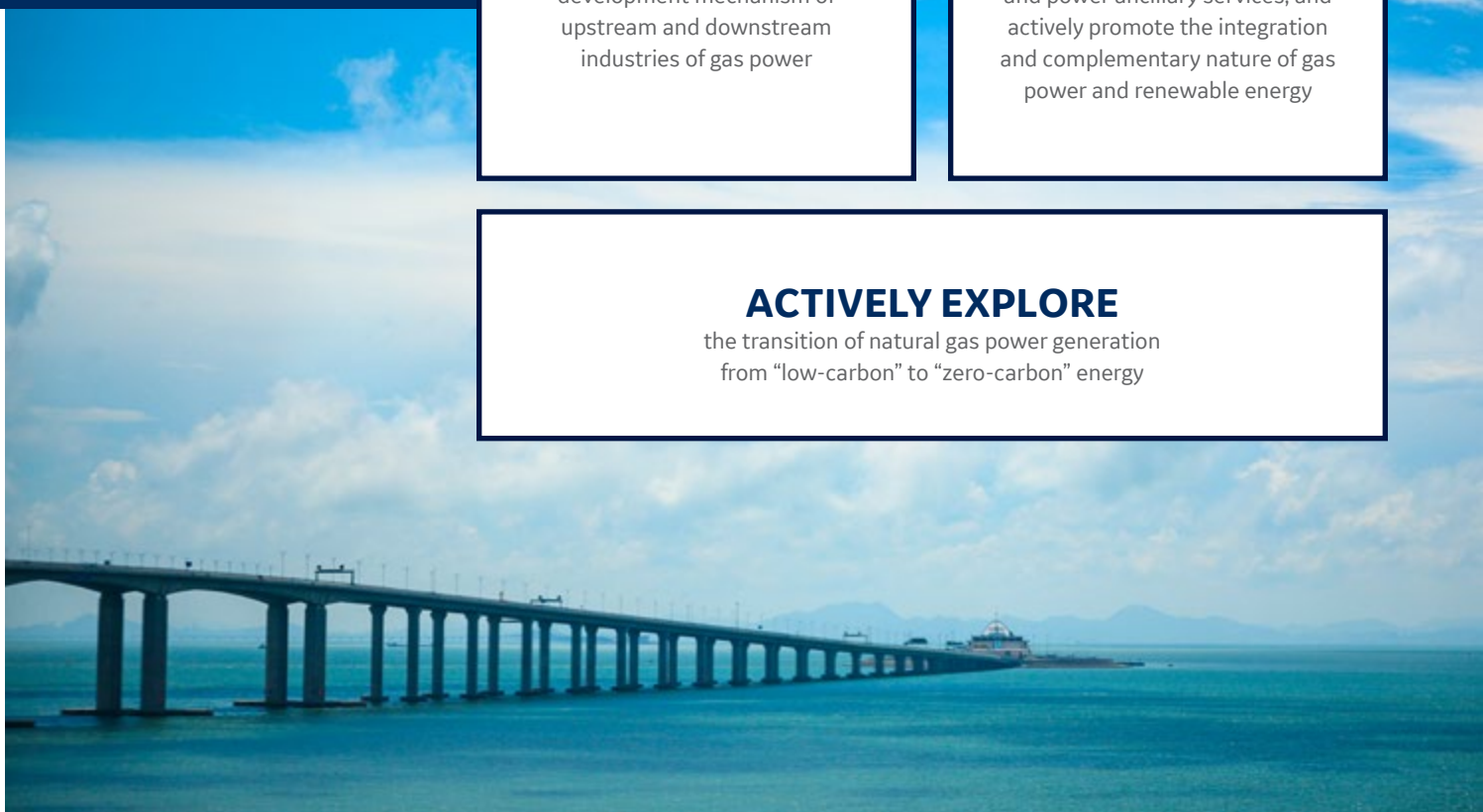
natural gas supply, establishing and improving the coordinated development mechanism of upstream and downstream industries of gas power

ESTABLISH

and improve market-oriented mechanisms of gas power linkage and power ancillary services, and actively promote the integration and complementary nature of gas power and renewable energy

ACTIVELY EXPLORE

the transition of natural gas power generation from "low-carbon" to "zero-carbon" energy



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China Will Witness Tremendous Gas Power Industry Growth During 14th FYP Period

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For more information see the full version of the China Future of Energy white paper at: www.ge.com/gas-power/future-of-energy