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Natural gas in China's power sector: Challenges and the road ahead

China's pledge to peak its emissions before 2030 suggests that decarbonization of its coal-dominant power sector will be key to fulfilling this goal. Natural gas emits around 50 per cent less greenhouse gases than coal when used in electricity generation.[1] With the rapid deployment of variable renewables, gas-fired power plants could also enhance the flexibility of the power system and boost renewables integration. However, the development of natural gas in China's power sector has been slow, with installed gas-fired capacity standing at 97 GW by October 2020 out of 2,100 GW total installed generating capacity, according to the latest data by the China Electricity Council.[2] This falls short of the target of 110 GW by 2020, set out in the 13th Five Year plan (2016–2020). Gas-fired generation only accounted for 3.2 per cent of China's total power production in 2019, significantly below coal's share of 62 per cent. Average running hours were 2,646 last year, indicating that gas-fired power plants have been underutilized.

This analysis discusses the latest developments in China's gas-fired power generation, the main challenges, and the road ahead both in the context of the upcoming 14th Five-Year Plan and the recently announced 2060 carbon neutrality goal. Expensive imported gas, costly turbine technology, and the lack of fully competitive electricity markets have been the main obstacles limiting the role of natural gas in China's power sector. Nevertheless, gas-fired power capacity could see faster growth in the 14th Five-Year Plan period compared to recent years, likely adding 40 to 50 GW of new capacity by 2025. The buildout will boost the gas fleet to 140–150 GW, up 50 per cent from current levels. Consequently, gas consumption in the power sector would grow by 40–50 per cent during this period, reaching 75–80 Bcm by 2025.

The policy framework will likely become more supportive for gas in power, as the government looks to limit coal consumption—in line with its goal of peaking emissions before 2030—and the rising needs of power system flexibility driven by renewables integration. Global gas prices could remain depressed by slack fundamentals[3] and this provides a good opportunity for China to ramp up gas utilization. Additional support could come from further liberalization in the domestic gas market, accelerated by the establishment of PipeChina, helping to reduce and deregulate natural gas prices. That said, concerns over gas import dependency might still dampen the growth outlook until China's domestic gas

[1] '2019 Refinement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories', *IPCC*, May 2019, https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html.
[2] 'China electricity sector in January to October 2020' (Chinese), *China Electricity Council*, 21 November 2020, https://cec.org.cn/detail/index.html?3-290358.
[3] Mike Fulwood, '$2 Gas in Europe: Groundhog Day?', Oxford Energy Comment, October 2020 https://www.oxfordenergy.org/publications/2-gas-in-europe-groundhog-day/.

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production is able to step up. Looking further ahead, China's 2060 carbon neutrality pledge would also mean the country needs to curb all fossil fuel consumption, including that of gas.

Moreover, the profitability of gas power plants faces challenges, with running hours squeezed by renewables and more cost-competitive coal-fired generation. In this context, the buildout of new gas capacity and the operation of existing gas plants will call for government subsidies to compensate for high costs. Consequently, the growth in buildout of gas-fired plants might be uneven across regions, with more plants likely being built in the coastal Eastern provinces which are relatively wealthier and have easier access to gas infrastructure.

Slow development of natural gas in China's power sector

Currently, natural gas plays a relatively small role in China's power sector despite the growth in recent years. Installed capacity of gas-fired plants has increased from only 26 GW in 2010, to 90 GW in 2019.[4] However, this is only 4.5 per cent of total generation capacity and less than 10 per cent of total thermal capacity. Last year's 236 TWh of gas-fired generation accounted for a meagre 3.2 per cent of total power production, significantly below coal's share of 62 per cent. In comparison, gas constituted 15 per cent of Germany's 2019 power generation mix and 40 per cent of the United Kingdom's generation mix in 2019.

Figures 1 and 2 show the development of China's installed power capacity and generation mix from 2010 to 2019. Coal remains the dominant fuel in China's power sector, but wind and solar generation have risen more rapidly than gas power, to 406 TWh and 224 TWh respectively in 2019.[5] Average utilization hours of gas plants have remained low, at around 2,500 hours per year, in contrast to coal plants averaging about 4,000 hours of operation in recent years.[6] Gas plants' running hours declined further in 2020, averaging only 2,123 in the first ten months this year.[7]

Figure 1: Installed power capacity, GW

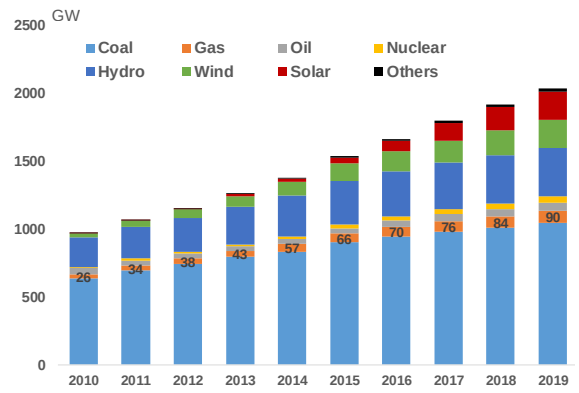
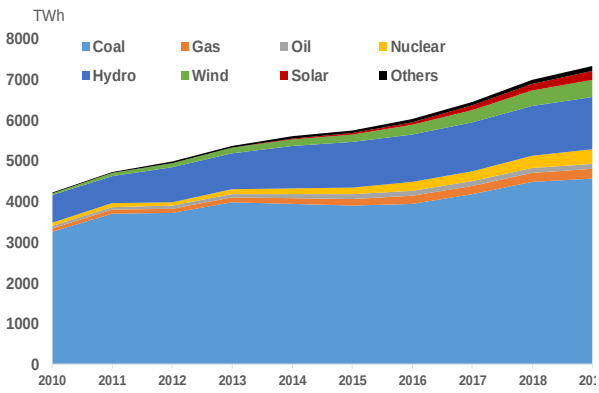


Figure 2: Power generation by source, TWh



Source: China Electricity Council, China National Bureau of Statistics

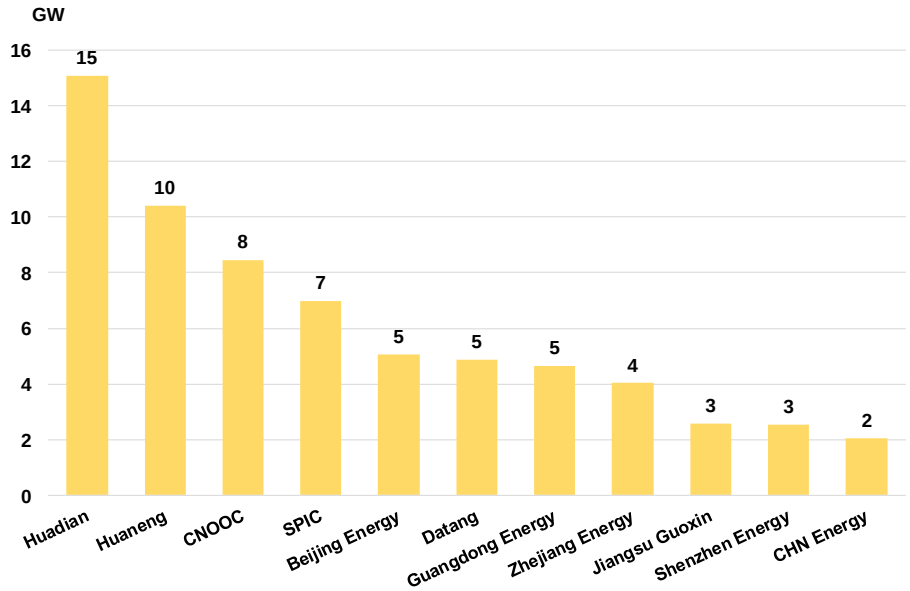
The majority of China's gas-fired power plants are located in the coastal regions, such as the Yangtze river delta, the Pearl river delta, and the Beijing–Tianjin–Hebei region, which are also China's large

[4] 'China electricity sector supply demand in 2019–2020' (Chinese), China Electricity Council, 21 January 2020, https://cec.org.cn/detail/index.html?3-277104.
[5] China electricity sector supply demand in 2019–2020' (Chinese), China Electricity Council, 21 January 2020, https://cec.org.cn/detail/index.html?3-277104.
[6] China electricity sector supply demand in 2019–2020' (Chinese), China Electricity Council, 21 January 2020, https://cec.org.cn/detail/index.html?3-277104.
[7] 'China electricity sector in January to October 2020' (Chinese), *China Electricity Council*, 21 November 2020, https://cec.org.cn/detail/index.html?3-290358.

industrial and manufacturing powerhouses covering 40 per cent of the country's total GDP. There are 90 gas plants in Guangdong, Jiangsu, and Zhejiang provinces with a total installed capacity of 50 GW, more than half of China's total gas-fired capacity, as shown in Figure 3. Beijing and Shanghai have 10 GW installed capacity each. This pattern is likely the result of stronger economic growth in these regions, and greater social consternation about deteriorating air quality, prompting them to subsidize gas power plants as they are struggling with profitability. Access to gas infrastructure and stable supply is another factor, since most of the newest gas plants have been developed in connection with the buildout of the West–East Gas Pipeline and LNG terminals.

Among major utilities, Huadian group and Huaneng group have relatively large gas fleets, owning 15 GW and 10 GW capacity each as of 2019. Figure 3 ranks major power companies by their gas-fired capacity. China National Offshore Oil Corporation has the third-largest gas fleet of 8.5 GW, building on its dominance in China's LNG industry. This is followed by State Power Investment Corporation (7 GW) and Datang (5 GW). The rest of the gas fleet is owned by provincial power companies in Beijing, Guangdong, Zhejiang, Jiangsu, and Shenzhen. The largest stated-owned utility, CHN Energy, only has 2 GW of installed gas capacity. This is in stark contrast to its 185 GW coal fleet. CHN Energy's reluctance towards gas plants might be explained by its reliance on coal mining, given that it also owns China's largest coal producer, Shenhua Group.

Figure 3: China installed capacity of gas-fired plants by power company, GW

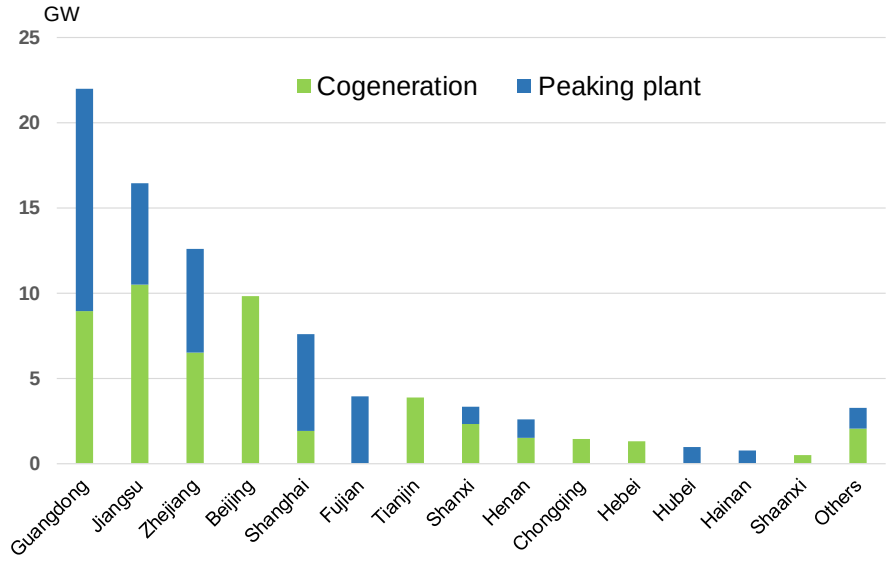


Source: China Electricity Council, Liu Zhitan (2020)[8]

In addition, Figure 4 depicts the shares relating to the two categories of gas-fired plants in China. Cogeneration plants, supplying heat to residential and industrial users, represent over 60 per cent of installed capacity, while the rest are gas peaking plants. All of the gas plants in the Beijing–Tianjin–Hebei region and Shanxi province are combined heat and power plants. For the rest of the provinces, about 30–50 per cent of gas-fired capacity consists of peaking plants, operating during periods of high power load or shortfalls of power supply.

[8] 'Gas power generation in China', *China 5e*, https://www.china5e.com/news/news-1101181-1.html, September 2020.

Figure 4: China installed capacity of gas-fired plants by province and by type, GW



Source: China Electricity Council, Zhu Xingshan (2020)[9]

Gas power capacity to fall short of target in 13th Five Year Plan

China's energy regulator has recognized the advantages of natural gas as 'clean energy' and has implemented policies to boost gas consumption in power and other sectors. However, total gas-fired capacity only stood at 97 GW by September 2020, according to the latest data by China Electricity Council.[10] This falls short of the target of 110 GW by 2020 set out in the 13th Five Year plan (2016–2020).

While the 13th FYP lays out the overall target for gas-fired power capacity, there are few specific policies aiming to boost gas usage in the power sector. The key policy documents to encourage gas deployment are the '*13th Five Year Plan for Natural Gas Development',*[11] and the '*Opinions on Speeding up Natural Gas Utilization'*[12] issued in 2017 by the National Development and Reform Committee (NDRC). In terms of gas in power, the FYP included priorities to develop gas peaking plants and combined heat and power plants, to ensure gas plants could supplement variable renewables production. It set a target of 110 GW of gas-fired capacity by 2020. The *Opinions* further set out details for developing gas distributed energy, exploring pilots in energy load centres such as industrial parks, business areas, and hospitals.[13]

Both documents stressed the advantages of developing gas-fired cogeneration in Northern China, to combat air pollution in the winter season. The Winter Clean Heating Plan in the Northern Area (2017–21) further promotes switching from aging coal plants to gas heating plants in this region, boosting the buildout of gas plants. However, the severe gas supply shortage in the 2017/18 winter season led to a

[9] 'Gas power generation in China' (Chinese), *China 5e*, https://www.china5e.com/news/news-1101181-1.html, September 2020.
[10] 'China electricity sector in January to October 2020' (Chinese), *China Electricity Council*, 21 November 2020, https://cec.org.cn/detail/index.html?3-290358.
[11] 'The Development and Reform Commission issued a notice on the "13th Five-Year Plan" for oil and gas development', Development and Reform Commission, 24December 2016, http://www.gov.cn/xinwen/2017-01/19/content_5161260.htm.
[12] 'Notice on the issuance of the Opinion on Speeding Up the Use of Natural Gas', National Development and Reform Commission Ministry of Science (et al.) 23 June 2017, http://www.gov.cn/xinwen/2017-07/04/content_5207958.htm.
[13] Even prior to the 13th FYP, in the 'Guidance on Gas Distributed Energy' from 2011, the NDRC had set a goal of building 1,000 gas distributed energy projects and increasing overall capacity to 50 GW by 2020. However, existing and planned projects had only reached 1.5 GW by the end of 2019, far below the target, mainly due to lack of funding.

significant reversal in the policy.[14] Since then, the regulator has changed the tone from promoting 'gas plants' to 'orderly developing gas peaking plants and limiting new build combined heat and power plants'. The emphasis in the winter pollution control policy also shifted to the replacement of dispersed coal, not mentioning any specific support for gas power. In November 2019, Premier Li Keqiang[15] further stressed provinces should '*utilize coal, gas, electricity whatever most accessible and economical for the region*' in ensuring winter energy supply security, thereby slowing the coal-to-gas conversion. Even the latest draft 'power sector integration plan'[16] by energy regulators made no specific mention of gas power in their 'Wind–Solar–Hydro–Thermal–Storage' concept.

Despite the recognition that natural gas can be beneficial for China's efforts to green its power system, a number of hurdles remain and have resulted in gas-fired capacity lagging behind the 13th FYP target. Subsequently, the role of gas has been quite limited in China's power system so far, due to its high costs and the reversal in policy support following the 2017 gas shortage. China's recent climate pledge of peaking emissions before 2030 and achieving carbon neutrality before 2060 has ignited optimism that gas, as a low-carbon energy source, could play a bigger role in the country's decarbonization pathway. The sections below will take a closer look at key challenges and the road ahead for the development of gas power in China.

Expensive imported gas a main obstacle for China's gas power

Fuel costs account for over 70 per cent of gas power generation costs, with the rest consisting of capital, maintenance, and operating costs. Therefore, gas prices have been the determining factor in the cost effectiveness of gas-fired generation. China's energy resource endowment is often described as '*Rich in coal, Poor in oil and gas*'. With nearly half of China's gas consumption dependent on imports via LNG or pipeline, gas has become a relatively expensive fuel in China compared to its abundant domestic coal supply. The more competitive costs of coal, the dirtier fuel, have therefore made it more appealing than gas in power generation. Thus, the running hours of gas plants have been squeezed by both coal-fired generation and renewables which have received a substantial policy boost. High fuel costs and low utilization hours have made most gas plants unprofitable and unable to recover their investments costs, leaving them largely reliant on subsidies.

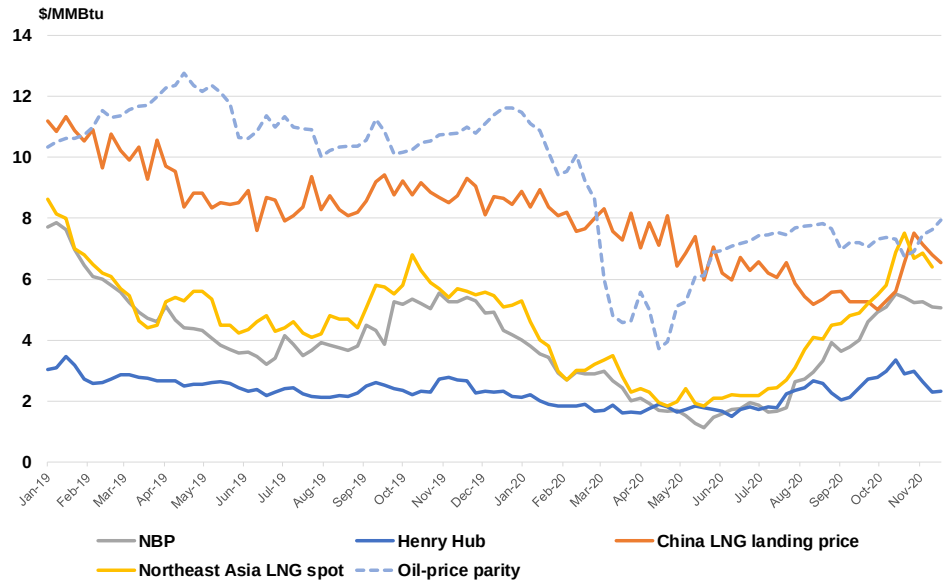
Gas prices in China are higher than in Europe and the US. In 2019, US Henry Hub natural gas prices averaged $2.53/MMBtu, and the UK NBP averaged $4.45/MMBtu; these figures were down 19 per cent and 44 per cent respectively from 2018 due to oversupply and slack demand.[17] In Asia, even though average LNG spot prices declined by 40 per cent year-on-year to $5.95/MMBtu, Northeast Asian long-term LNG prices still averaged $9.43/MMBtu last year.[18] Most Chinese importers have locked their LNG purchase in long-term contracts and have been unable to enjoy the benefits of low global gas prices. Including transportation costs, Chinese end-use gas prices were around $10–15/MMBtu in 2019 for the commercial, industry, and transport sectors.[19] For power generators in coastal provinces and the Beijing–Tianjin region, the gas purchasing cost has been around CNY2–2.5/m^3, or up to CNY3/m^3 in peak season.[20] This translates to a fuel cost of CNY0.5–0.6/kWh for gas generation, which is higher than the average fuel cost of CNY0.2/kWh for coal plants (with imported coal price at CNY400/ton). In

[14] Akira Miyamoto and Chikako Ishiguro, 'The Outlook for Natural Gas and LNG in China in the War against Air Pollution', OIES, December 2018, https://www.oxfordenergy.org/publications/outlook-natural-gas-lng-china-war-air-pollution/.
[15] 'News on National Energy Commission meeting' (Chinese), 11 October 2019, http://www.gov.cn/guowuyuan/2019-10/11/content_5438589.htm.
[16] Consultation on 'Opinions on Wind-Solar-Hydro-Thermal-Storage Integration and Generation-Grid-Load-Storage Integration' (Chinese), *NDRC and NEA*, 27 August 2020, https://www.ndrc.gov.cn/hdjl/yjzq/202008/t20200827_1236908.html.
[17] 'China Natural Gas Development Report (2020)', *National Energy Administration*, September 2020.
[18] same source as 16.
[19] Michael Xiaobao Chen, 'Potential and challenges of China's second-tier LNG importers', Oxford Energy Forum, September 2020: ISSUE 125.
[20] 1 USD ≡ 6.8 CNY.

a few provinces, such as Jiangsu province, gas plants get direct supplies from pipeline or LNG terminals, and their gas costs are slightly lower at CNY0.4–0.45/kWh.

This year, global gas prices plunged further on abundant supply and the effects of COVID-19 curbing demand, with spot LNG contracts crashing to below $2/MMBtu in May. China's imported LNG price (landing price excluding tax and fees) has also been on a declining path, falling from $9/MMBtu in January to $5–6/MMBtu at present, down 50 per cent. As a result, fuel costs for Chinese gas plants have also declined, to CNY0.3–0.5/kWh, depending on the source of supply. However, this is still higher than the fuel costs of coal plants, especially with coal prices falling alongside weakness in gas prices.

Figure 5: Global gas price development since 2019, weekly average in $/MMBtu



Source: Refinitiv Eikon, Shanghai Petroleum and Natural Gas Exchange, Waterborne LNG Data

However, even this temporary relief in fuel costs might prove short lived for gas plants in China. Global gas prices have gradually recovered since September, driven by higher winter demand and lower Dutch production and US LNG supply. US Henry Hub spot prices rebounded to $3.354/MMBtu, while LNG spot contracts rose to $7.5/MMBtu in late October, the highest level this year. Therefore, expensive fuel costs will remain a drawback for gas power in China, deterring its development.

Moreover, the lack of carbon pricing in China means that the advantage of gas plants in terms of carbon emissions compared to coal power is not fully reflected in prices. In Europe, the carbon market has been in place since 2005 and the EU ETS allowance price has risen above €20/t in recent years. These high carbon prices had the effect of lifting coal plants' carbon costs and marginal costs, making coal a less competitive fuel than gas. However, China is about to launch its national carbon market in 2020, covering the power sector. Seven pilot ETS schemes have been in operation since 2013, but allowance prices have been at rather low levels, between $3–14/t. This level of carbon price has a limited impact on the economics of coal plants. While the development of the ETS could raise the cost of coal-fired power, it could also make gas less competitive than zero-emission renewables. And in the near term, the highly regulated power market structure, together with the dominance of coal in the power mix, makes coal-to-gas switching challenging. Thus, the structure of China's power market and pricing system mask the environmental and climate benefits of gas plants over coal.

Costly turbine technology another obstacle for gas plants in China

In addition to the cost of fuel, costly turbine technology and dependence on foreign manufacturers also drive up the costs of gas-fired generation in China. Currently, Chinese companies are lagging behind

their international peers in terms of gas turbine technologies. Following years of cooperation with international counterparts in turbine production, Chinese companies are estimated to be able to produce around 70 per cent of the country's requirement of gas turbine components domestically. However, the manufacture of core components, certain types of technologies, regular inspection, and maintenance are still dominated by foreign producers, driving up the cost of gas plants.

Technical equipment accounts for 50 per cent of upfront investment costs. Most of the gas power plants in China are equipped with 9E and 9F class gas turbines. Leading turbine producers SIEMENS and General Electric have already developed more advanced 9H class turbine types, which improve efficiency, start-up time, emissions, and flexibility still further. The H-class gas turbine could reach a thermal efficiency of 64 per cent – nearly 20 per cent higher than a modern ultra-supercritical coal plant. China Huadian group used 9H class turbines from SIEMENS in its newest Guangzhou Zengcheng combined cooling, heat, and power plant (CCHP) project. This is China's first H-class gas power plant; it consists of two 670 MW power generating units and has just completed a 168 hour pilot run. Despite its advantages, the latest H-class gas turbine would cost CNY2,300–2,400/kw, 30 per cent higher than coal plants of the same class.[21]

In addition to fuel and equipment costs, maintenance is the main part of a gas plant's operational costs. However, most of the gas plants in China rely on service agreements with foreign turbine manufacturers. One major maintenance cycle could cost as much as $60 million, rather significant for a medium-sized plant. Many components of the gas turbine need to be sent to the original producers for inspection and repair, since they are the only supplier and qualified inspector. This technical dominance leads to rather costly maintenance and inspection, and curbs further the deployment of gas plants in China.

Consequently, high fuel prices and operational costs have resulted in the levelized cost of electricity from gas-fired power plants staying above the levelized costs of coal power.[22] In addition, despite gas generation's advantage in terms of lower pollutants, elevated costs also make the conversion of power plants from coal to gas generation rather uneconomical compared to retrofitting with ultra-low emissions technology to reduce SOx, NOx, and soot emissions. It is estimated[23] that it costs on average CNY208/kW to retrofit a 300 MW-class coal plant to ultralow emissions, making the coal plant's power generation costs CNY0.16–0.40/MWh higher. As a result, coal generation costs could rise to CNY0.466/kWh with the coal price at CNY600/t. In contrast, conversion of a power plant from coal to gas generation would cost CNY1,037/kW and gas power generation costs would reach CNY0.7–0.85/MW, with a gas price at CNY2–2.5/m^3.

Yet this obstacle could be removed gradually in the future, as Chinese power companies strive to be less dependent on international producers in gas turbine technology. The State Power Investment Corporation (SPIC) formed China United Gas Turbine Company (UGTC) to achieve the indigenous production of heavy duty gas turbines. Harbin Electric, Shanghai Electric, and Dongfang Electric are also shareholders of UGTC. The goal is to complete the design and development of 300 MW F-class heavy duty gas turbines by 2023 and to finalize the development of 400 MW G/H-class turbines by 2030. UGTC have also signed an agreement with Ansaldo Energia in heavy duty gas turbine technology collaboration. Both Harbin Electric and Shanghai Electric have formed joint ventures with foreign producers to manufacture some components in China, thus providing local one-stop maintenance services for domestic gas power plants. Thus, steady progress in domestic gas turbine technology could help to bring down the investment and operational costs of gas power plants in China in the future.

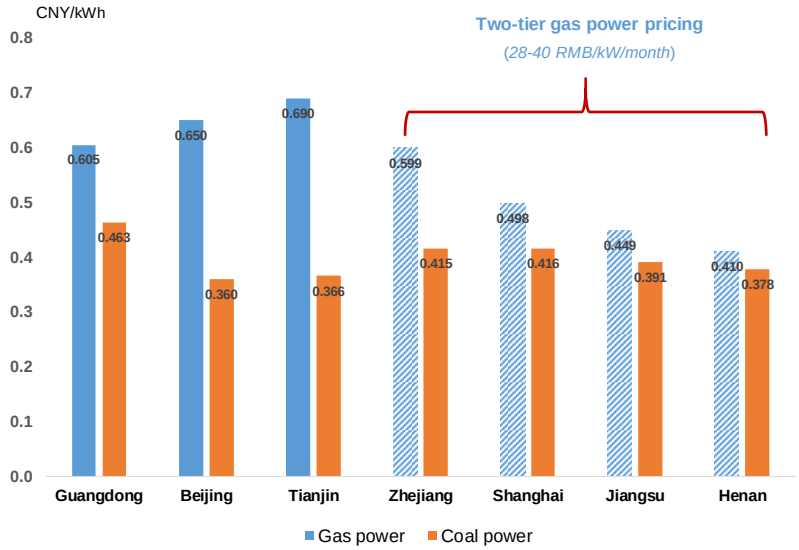
[21] 'Clean, reliable and expensive, how can gas power show its advantage?' (Chinese), *Caijing magazine*, 17 August 2020, https://news.caijingmobile.com/article/detail/421064?source_id=43.
[22] 'The Role of Gas in Today's Energy Transitions', IEA, July 2019, https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions.
[23] 'Cost comparison of coal-to-gas conversion vs ultralow-emission technology retrofitting' (Chinese), BJX news, June 2018, http://news.bjx.com.cn/html/20180611/904673.shtml.

Absence of competitive liberalized electricity markets

In addition to relatively low carbon emissions, their flexibility makes gas plants the ideal supplementary generators in the power system, as the share of variable renewables increases. In fully competitive power markets, the price difference between peak and off-peak could reward flexible gas plants. However, over 70 per cent of power generation in China is still under regulated benchmark power prices, even though it has been five years since the latest round of power sector reforms kicked off in 2015. The ancillary services market is also in its infant stage, deterring the development of flexibility services. Against this backdrop, gas plants cannot raise sufficient revenues from the power market, and remain largely unprofitable.

Also, the rather rigid power price structure does not allow gas plants to fully recover their investment costs. China's energy regulator has been cautious about raising power prices and tends to favour flat price levels. Thus, gas generators could not benefit from high peak-hour prices as is the case in liberalized power markets. In 2020, due to the COVID-19 pandemic, energy regulators have cut power prices by 5 per cent for industrial and commercial businesses.[24] With economic recovery and a reduction in enterprises' cost burden in focus, the policy preference for capping power prices could persist into next year too. Due to relatively expensive fuel costs, regulated power prices are higher for gas plants than for coal. The NDRC 'Notice on gas power price' from 2014 is the only national-level regulation on gas power pricing. It states that gas power prices could vary according to generator type (cogeneration or peaking), and shall not exceed the benchmark coal power price by more than CNY0.35/kWh. Each province is then free to determine and adjust its gas power price, especially when gas prices fluctuate significantly.

Figure 6: Benchmark coal and gas power prices in selected provinces (CNY/kWh)



Source: Provincial DRC

Benchmark coal and gas power prices in selected provinces are depicted in Figure 6. In Guangdong, Beijing, and Tianjin, gas plants could fetch CNY0.605–0.69/kWh, around CNY0.2–0.3/MWh higher than coal plants. In July 2020, Guangdong NDRC revised down its gas power benchmark price from CNY0.665/kWh to CNY0.605/kWh citing lower LNG spot prices. Zhejiang also launched pilots of gas power on parity with coal. Nevertheless, this gas price range is largely insufficient to cover the fuel and operational costs of gas plants, meaning they still rely on government support.

[24] 'Notice on reducing power prices for enterprises' (Chinese), NDRC, June 2020, https://www.ndrc.gov.cn/xxgk/zcfb/tz/202006/t20200628_1232199.html.

The gas to coal power price premium is smaller in Zhejiang, Shanghai, Jiangsu, and Henan. This is because these four areas have implemented a two-tier gas power pricing mechanism in recent years,[25] consisting of a fixed gas power capacity payment of between CNY28–42/kW/month and a variable standard benchmark price per kwh. The aim of this mechanism is to support gas plants, with capacity payments covering fixed costs, whereas the energy price component will be in line with gas fuel costs. However, with running hours at very low levels, such as 1,000 hours in Zhejiang, gas plants are still largely unprofitable.

With the spot market still in a testing phase, most commitments and dispatches of generators are guided by instructions from economic planning agencies within provincial governments, under the five-level hierarchy of dispatch organizations.[26] The operations of power plants are mainly determined by safety dispatch rather than economic dispatch. This means that the dispatch centre tends to keep reserve margins for the power system at rather high levels to ensure power supply. Coal plants are usually required to keep running at 50–60 per cent load. Consequently, these coal plants would often also be dispatched for peaking purposes, squeezing the running hours of gas plants.

The aim of the ongoing process of power sector reform is to gradually move from a regulated electricity market toward a competitive market. However, there is still a long way to go. Eight provinces started with spot power trading last year, but they have been mostly conducting test trading and settlement. For example, Zhejiang province conducted the first round of test trading in 2019 with seven days of continuous settlement. The daily average bidding price of gas power generators were in the range CNY0.679–0.716/kWh, more than double the coal generators' bidding price. As a result, gas plants did not get dispatched in the spot market, curbing their running hours and profits. In addition, most of the spot pilots set a bidding cap (in the range CNY0.8–1.5/kWh), which could also limit the incentive for gas peaking generators.

Guangdong province, with the largest gas fleet in China, conducted a one-month continuous test of spot trading in August 2020. Around 70 gas generators and 130 coal generators participated. Between 50 and 70 GWh were traded on the spot market per day, equal to 6–8 per cent of daily power generation. As Figure 7 shows, the day-ahead price spiked to as high as CNY1.2/kWh, benefiting gas generators. However, most off-peak hours saw prices at CNY0.07/kWh, which is the minimum bidding price. Therefore, this dragged down the average clearing price to CNY0.114–0.275/kWh per day during the month. This is below the benchmark coal power price of CNY0.463/kWh, and far below the marginal costs of gas generators.

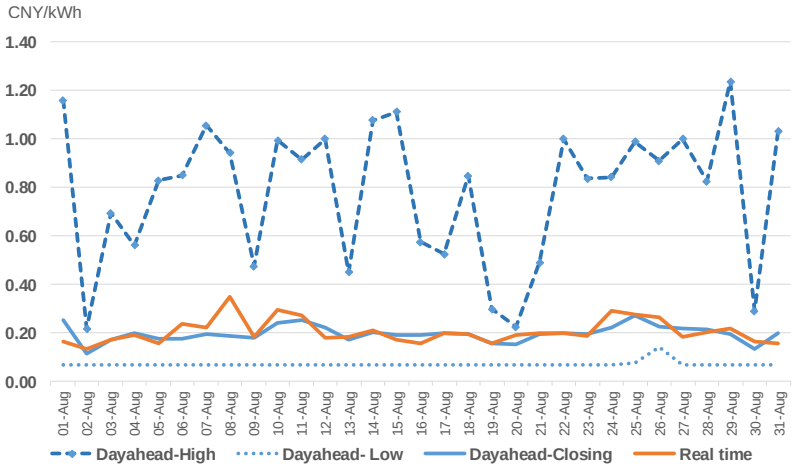
The low spot price is mainly due to the fact that over 90 per cent of generation is still covered by long-term power trading (bilateral contracts) and regulated benchmark prices. Thus, in the spot market, producers would just bid low prices to keep them in the dispatch and execute the long-term contracts, even below their marginal costs. One gas plant in Guangdong reported that, after accounting for both spot price and long-term contracts, its August power generation was sold at CNY0.61/kWh, below the benchmark price. The low price level in the spot market could not compensate the core value of gas power, in other words, flexibility.

In addition, due to the COVID-19 crisis and economic slowdown, the NDRC reduced electricity prices by 5 per cent in February in order to reduce energy costs for enterprises. This could remain as a preferred policy in order to facilitate economic recovery, meaning that regulated benchmark power prices for both coal and gas are unlikely to rise in the near term. Against this backdrop, the outlook for gas power plants' revenues from electricity sales is rather bleak.

[25] Report on 'Review of electricity price mechanism in China' (Chinese), *Ping An Securities*, April 2019, http://pdf.dfcfw.com/pdf/H3_AP201904251322714397_1.pdf.

[26] Mun S. Ho, Zhongmin Wang, and Zichao Yu, 'China's Power Generation Dispatch', *Resources for the Future*, April 2017, https://media.rff.org/archive/files/document/file/RFF-Rpt-ChinaElectricity.pdf.

Figure 7: Guangdong spot power test trading August 2020 Day-ahead and Real time price, in CNY/kWh



Source: Guangdong Power Exchange

Concerns over rising gas import dependency weigh on policy making

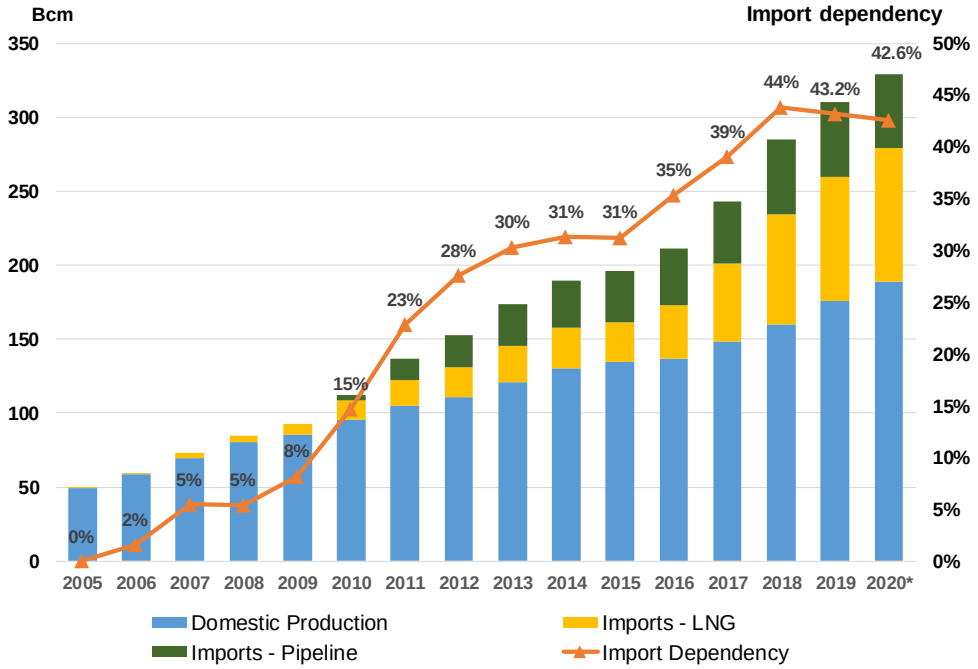
Another factor behind the slow development of gas power is the concerns over high gas import dependency and gas supply. In 2019, China's total gas consumption increased by 8.6 per cent year-on-year and reached 306.4 Bcm, accounting for 8.1 per cent of primary energy consumption. Gas use in the power sector accounted for 17.8 per cent of the total, below urban gas and industrial sectors' shares of 37.2 per cent and 35.0 per cent, respectively.[27]

Imports represented 43 per cent of China's 2019 gas demand, slightly below the 44 per cent seen in 2018. Figure 8 shows that gas import dependency has increased rapidly since 2005, following the steady rise in China's gas consumption. Despite the impacts of the COVID-19 pandemic and economic slowdown, China's gas consumption is expected to grow by 7 per cent to 320 Bcm in 2020, with LNG imports potentially rising to 90 Bcm and pipeline imports stable at 50 Bcm. Consequently, China's gas import dependency will be 42.6 per cent in 2020, slightly below the 2019 level but still relatively high.

China is now the world's second-largest LNG importer, just after Japan, with yearly imports rising steadily since 2010. In particular, solid policy support for 'coal to gas' conversion to battle air pollution boosted LNG imports significantly in 2017. However, the subsequent gas supply shortage in winter 2017/18 led to worries over gas import dependency and gas availability. This concern is often brought up in domestic debate over the role of gas in China's future energy system, since domestic production is unlikely to rise significantly in the near term despite a strong policy push for domestic exploration since 2018.[28] Consequently, a rapid uptick in gas consumption in both power and other sectors will have to be met with imports. Given the sheer size of China's energy demand, experts have estimated that when gas accounts for 15 per cent of China's energy consumption, China's gas consumption could represent 50 per cent of global gas trades.[29] Thus, the potential high reliance on imports is viewed as hampering energy security, which will continue to influence upcoming policy discussions over the pathway of gas in China.

[27] 'China Natural Gas Development Report (2020)', *National Energy Administration*, September 2020.
[28] Erica Downs, 'Supply security concerns are supporting the liberalization of China's oil and natural gas industry', Oxford Energy Forum, September 2020: ISSUE 125.
[29] Jiang Yi, 'China future energy scenarios and building sector's low carbon path' (Chinese), November 2019, https://www.shangyexinzhi.com/article/308483.html.

Figure 8: China natural gas consumption, domestic production and imports, Bcm



Source: China Customs, China National Bureau of Statistics

New gas-fired capacity of 40–50 GW expected in the 14th Five Year Plan

Gas being a low-carbon fuel, and gas power plants' advantage of boosting power system flexibility, are both well recognized. And given the increase in gas-fired power plants over the past decade, some growth in gas-fired capacity in the years to come is likely, despite the slower than planned development and obstacles discussed above. Currently the country is in the process of drafting the 14th Five Year Plan, which is the blueprint for economic and energy policies for the 2021–2025 period, and will be finalized in March 2021. Enhancing the flexibility of the power system is one of the priorities in energy policy planning in light of rising needs for renewables integration. Therefore, the 14th FYP could turn more favourable towards the development of gas power, potentially implementing robust policy support to build out more gas-fired capacity, despite the high costs discussed earlier.

China's power system is facing a structural dilemma: abundant generation vs lack of peaking capacity. China's total installed generating capacity has been increasing in recent years, as shown in Figure 1, mostly driven by wind and solar capacity additions. But this has exacerbated the intermittency problem and there is insufficient 'flexible' (ramping) capacity to balance intermittency, especially during times of high demand, such as that seen during August 2020.[30] Several provinces experienced record high loads in summer 2020 amid heatwaves and ramping of industrial activities post COVID. With the rapid progress in variable renewables and energy storage still not being commercially viable for large-scale utilization, challenges to balancing the power system will call for the deployment of more flexible generation, including gas.

So far, the policy emphasis has been on technical upgrading of the coal fleet, since coal is the dominant fuel in the power mix. The 13th FYP set an ambitious target of retrofitting 220 GW coal plants for flexibility upgrades by 2020. However high costs and lack of incentives have deterred progress,[31] with

[30] 'Record high power load in 12 provincial grids'(Chinese), *SASAC*, August 2020, http://news.bjx.com.cn/html/20200821/1098890.shtml.
[31] 'Why is the coal plant upgrading slow in China?' (Chinese), *China5e*, June 2020, https://www.china5e.com/news/news-1092924-1.html.

only 25 per cent of the planned upgrading capacity accomplished. Various stakeholders are debating intensively over China's coal pathway in the 14th FYP. A few institutions[32] suggest building a further 200–300 GW coal-fired capacity by 2025, in order to meet the growth in power demand and peaking load needs. In contrast, other organizations weigh in with the urgency of the low-carbon transition and expect the gap in generation to be filled mostly with renewables supplemented with gas capacity, followed by battery storage and pumped storage hydropower.

In its latest report on the power sector's 14th FYP,[33] the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) forecast that coal capacity shall be capped by the energy regulator at 1,100 GW in 2025, namely the same level as in 2020. It then suggested increasing gas installed capacity to 152 GW, meaning an addition of around 62 GW from the 2019 level. Several other gas market experts and organizations[34] also suggested increasing installed gas capacity to 140–150 GW by 2025, accounting for nearly 6 per cent of total generating capacity. The State Grid researchers[35] expect China's gas capacity to increase only slightly, to 120 GW by 2025, as coal and renewables capacity will grow further in the power mix. In contrast, China Electricity Council suggested boosting gas-fired capacity strongly, to 179 GW by 2025,[36] but this is likely to face strong objections given that the current situation of costly fuel and expensive turbine technology is unlikely to improve for gas power in the short term. Power sector reform is only likely to proceed gradually, suggesting that it will take time before gas power can rely on a competitive power market. The profitability of gas power plants will remain challenging amid high costs and regulated electricity prices, combined with low running hours squeezed by coal and renewables. In this context, the buildout of new gas capacity and the operation of existing gas plants will most likely be supported by government subsidies.

China's gas power development may maintain the current pattern across regions, with new capacity expected to be built mostly in relatively wealthy coastal provinces in the Yangtze river delta and the Pearl river delta. The China Electricity Council's assessment report on the 13th FYP[37] briefly mentioned the challenges to gas power and suggested the same regional distribution, focusing on coastal provinces. Lately, Guangdong province released its 2021–2025 action plan on 'Fostering strategic new energy sector development', aiming to boost gas-fired capacity by 20 GW to 42 GW by 2025. Jiangsu province plans to increase its gas fleet to 20 GW by 2020, and grow further. A similar trend is expected in Zhejiang province. One driver is that these provinces have set out ambitious plans to ramp up clean energy deployment, developing renewables, and reducing coal consumption. Gas power is then relatively attractive among types of new generating capacity despite its high costs, since these wealthier provinces could afford generous subsidies to gas plants. The flexibility of gas plants could also facilitate the development of offshore wind power in these regions. In addition, the coastal region is expected to see further growth in LNG infrastructure. This would improve gas supply availability for power plants, together with potentially lower fuel costs, with power plants securing direct supply agreements with gas suppliers. The central region could also see some room for building gas plants, if the government sets stricter rules on environmental protection and emissions. Under the pledge of peaking emissions before 2030, the central coal-heavy provinces would need to implement plans to limit and curb coal consumption, and develop a low-carbon energy system. But fiscal capability in the central provinces would be more constrained than in coastal regions, limiting their willingness to subsidize unprofitable

[32] 'China Electricity Generation Development Report 2020' (Chinese), *State Grid*, July 2020, http://shoudian.bjx.com.cn/html/20200713/1088281.shtml.; 'China EPPEI released new report on China Electricity Development 2019' (Chinese), *Xinhua*, July 2020, http://www.xinhuanet.com/energy/2020-07/31/c_1126308289.htm.

[33] Report on 'China Energy Transition and 14th Five Year Plan for power sector' (Chinese), *GEIDCO*, July 2020, https://www.geidco.org/html/qqnyhlw/zt20200731/index.html.

[34] Liu Zhitan, 'Discussions on development of gas power in the 14th Five Plan' (Chinese), September 2020, http://news.bjx.com.cn/html/20200929/1107768.shtml.

[35] 'China Energy and Power Development Outlook 2020', State Grid, November 2020, https://mp.weixin.qq.com/s/GFAXCCLetyhxAaPXWZCyXg

[36] 'China Electricity Council expects power demand growing to 9500 TWh by 2025', (Chinese), Sina News, 22 January 2020, https://finance.sina.com.cn/wm/2020-01-22/doc-iihnzahk5754395.shtml.

[37] 'An assessment of the power industry's 13th FYP at mid-point', (Chinese), China Electricity Council, 18 March 2019, http://shupeidian.bjx.com.cn/html/20190318/969403.shtml.

gas plants. In this context, central government would need to step in and lend financial support for gas power development.

In terms of the type of gas plants, the power systems of Beijing and Shanghai are already rather saturated with large-scale gas power plants. Coastal provinces could also see limited scope for large-scale gas power plants after a few years. Guangdong could develop further distributed energy projects in combination with medium-sized gas power plants, after accomplishing the 11 combined heat and power projects and 26 distributed gas energy projects in the 13th FYP. Moreover, central and northeastern provincial capitals and major cities might prioritize the growth of cogeneration plants.

A gradual development of efficient carbon pricing could lend additional support to gas plants in China. To start with, the forthcoming national carbon market will cover the power sector. The latest draft ETS allocation plan, from November 2020,[38] shows that gas power plants will not have compliance obligations. Gas plants will receive allowances based on a benchmark of around 0.4 t CO_2/MWh, and can sell surplus allowances if there are any. This initial setup in the carbon market aims to relieve the burden on gas plants due to high costs. With the aim of expanding the ETS to industry sectors by 2025 and the goal of peaking emissions by 2030, gas plants could see the exemption withdrawn in subsequent years, and they will also need to comply in the same way as coal plants do. At present, the intensity-based target of the ETS would mainly contribute to improving the overall efficiency of the coal fleet, rather than to absolute emissions reductions. But the climate goal of emissions peaking before 2030, followed by a declining path, will require the ETS to set a tougher reduction target. So, China's ETS will likely switch to an absolute cap, as in the EU ETS, once the national carbon market is fully established and runs smoothly. By then, a robust carbon price signal could increase the cost of coal plants to the relative advantage of gas power plants.

Gas unlikely to receive significant boost under the 2060 carbon neutral goal

Looking further ahead, the outlook for gas consumption and gas power could turn brighter with China's recent climate pledge of carbon neutrality before 2060. To reach net-zero emissions by 2060 would require a drastic transformation of China's energy mix, meaning that the current 85 per cent share of fossil energy consumption would need to decline drastically in the next four decades. Thus, coal consumption will be limited and reduced gradually, which provides some room for low-carbon energy sources such as gas to grow in the medium term. However, the goal of curbing fossil energy consumption will then also limit the scope of gas deployment along the pathway, since a zero-emissions power system will be mainly based on renewables. Deep electrification will be essential to fully decarbonize the energy system, and the increase in generating capacity will be filled largely with renewables to bring down emissions. Expectations[39] are that annual power generation could double from the current level of 7,300 TWh, while wind and solar generating capacity would need to grow tenfold to reach a combined capacity of 5,000–6,000 GW by 2050.

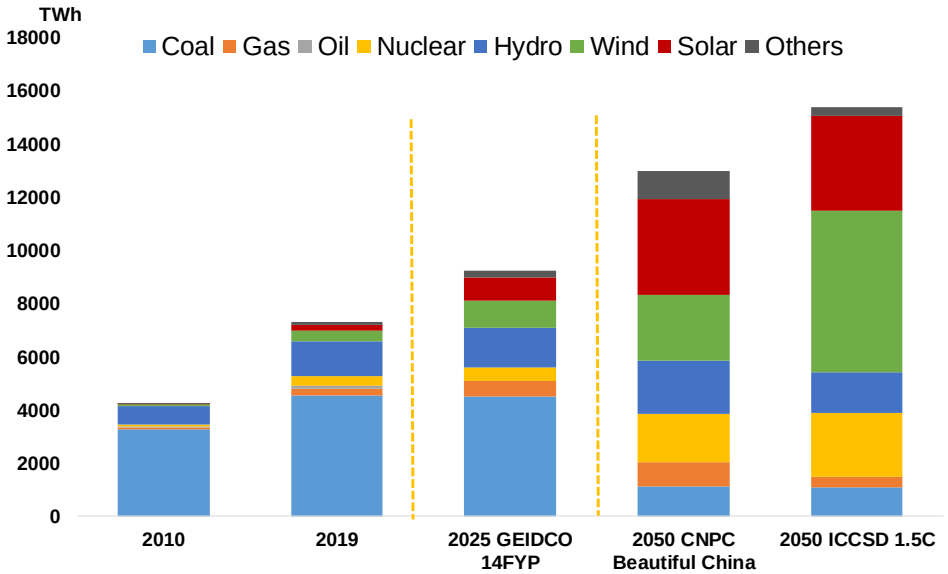
In October, China's leading climate think tank, Tsinghua University's Institute for Climate Change and Sustainable Development (ICCSD) published key findings from the China low-carbon pathway project,[40] mapping out emissions and energy mix scenarios, including a 2050 net-zero pathway. The study proposed to limit coal consumption by as early as 2025, and showed that the share of gas in China's energy mix could increase from its current level of 8.5 per cent to 11 per cent in 2025, followed by 13 per cent in 2030. So, the policy recommendations from this prominent Carbon Neutral pathway project envision limited growth in gas power in the next few years. However, Professor He Jiankun, who

[38] 'Consultation on the draft National ETS Allocation Plan 2019–2020' (Chinese), China Ministry of Ecology and Environment, 20 November 2020, http://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202011/t20201120_809087.html.
[39] 'How China could be carbon neutral by mid-century', *Nature News*, 19 October 2020, https://www.nature.com/articles/d41586-020-02927-9.
[40] Slides on 'China's Long-term Low-Carbon Development Strategy and Pathway', *Tsinghua ICCSD*, 12 October 2020, https://mp.weixin.qq.com/s/S_8ajdq963YL7X3sRJSWGg.; Lauri Myllyvirta, 'Influential academics reveal how China can achieve its "carbon neutrality" goal', 14 October 2020, https://www.carbonbrief.org/influential-academics-reveal-how-china-can-achieve-its-carbon-neutrality-goal.

is leading the project, stressed that[41] 'China is still expected to see growth of natural gas consumption in 2026–2030, so the growth of carbon emissions from gas use should be offset by the reduction from coal sector.'

Indeed, in the 1.5-degree scenario from the ICCSD project, installed gas-fired capacity will grow to 200 GW in 2050 and gas generation (with carbon capture and storage) will be 3 per cent of the total power mix. Figure 9 depicts the power mix in 2025 from GEIDCO's 14th FYP report discussed above, and China's 2050 power mix from two low-carbon scenarios.

Figure 9: China power generation mix in 2025 and 2050 scenarios, TWh



Source: China Electricity Council, GEIDCO, CNPC, Tsinghua ICCSD

So, the ICCSD scenario foresees an even lower gas share in the 2050 power system, compared with the most environmentally ambitious scenario in China National Petroleum Cooperation's (CNPC) Energy outlook 2019.[42] The 2019 'CNPC Beautiful China' scenario expects gas-fired capacity to remain at 300 GW in 2050 and gas power generation to comprise 7 per cent of total power generation by that time. Both of the 2050 scenarios expect the remaining coal and gas power generation to be retrofitted with CCS. Of course, it remains to be seen whether these scenarios will be finally adopted into the 14th Five Year plan, the 2035 Beautiful China vision, and the 2060 carbon neutrality pathway. But these modelling results are providing some indications on policy recommendations for the pathway ahead.

Conclusion

Gas, when used in power generation, has an environmental and climate advantage over coal. However, China's gas-fired generating capacity only stood at 97 GW as of October 2020, falling short of the targeted 110 GW gas capacity in the 13th FYP. Unfavourable plant economics due to high fuel prices and the rigid electricity pricing mechanism are the main factors behind the lagged development, making gas struggle to compete with coal and renewables in China. With highly regulated power prices and reluctance on the part of energy regulators to raise power prices, gas generators struggle to fetch

[41] 'China's top climate think tanks push for more cuts to coal use and emissions: report', *Reuters*, 12 October, https://de.reuters.com/article/us-climate-change-china/chinas-top-climate-think-tanks-push-for-more-cuts-to-coal-use-emissions-report-idUSKBN26X0SV.

[42] Michal Meidan, 'Glimpses of China's energy future', Oxford Energy Comment, September 2019, https://www.oxfordenergy.org/publications/glimpses-of-chinas-energy-future/.

enough revenues to cover investment costs. Thus, recent developments in gas power have been concentrated in relatively wealthier coastal provinces, which can afford high subsidies for unprofitable gas plants. The 2017 gas shortage has also triggered a temporary reversal in the initial policy framework, due to concerns over gas supply and import dependency.

Nevertheless, China's recent pledge of peaking emissions before 2030 and achieving carbon neutrality before 2060 has injected some optimism over the development of gas power. To achieve its carbon neutrality goal, China's power system would need to eliminate coal and reach zero-emissions by 2050, at the latest. Rapid uptake in renewables would also call for more flexible services, including gas, until battery storage becomes widely commercially viable. Therefore, the upcoming 14th Five-Year Plan will likely adopt favourable policies supporting the buildout of gas plants, for the purpose of replacing retired coal plants and supplementing renewables as flexible generation. A further 40–50 GW new gas capacity could be built by 2025, boosting the gas fleet to 140–150 GW, 50 per cent higher than current levels. Consequently, gas consumption in the power sector would grow by 40–50 per cent during this period, reaching 75–80 Bcm by 2025. With the expectation that China's total gas demand could almost double in the next decade[43] to 550–600 Bcm (by 2030), gas power's growth will contribute to incremental demand through 2030.

That said, it is uncertain whether the growth in gas demand will be met with imports or domestic production. PetroChina[44] also predicts massive Chinese gas demand growth following the carbon neutrality pledge, reaching 600 Bcm by 2030, and 620 Bcm by 2035. But it also expects the majority of increased gas demand to be met with a rapid uptick in domestic gas supply capacity, reaching 520 Bcm by 2035, comprising 220 Bcm conventional gas, 100 Bcm shale gas, 50 Bcm coal-bed methane (CBM), and 150 Bcm coal-derived synthetic natural gas (SNG). Therefore, the space left for imported gas will be determined by the speed of ramping up domestic production.

Further liberalization of the gas market could also accelerate in the next few years,[45] with the newly established PipeChina driving gas infrastructure unbundling and creating more competitive domestic markets. Improvements in the gas pricing mechanism will then benefit gas power plants as well. New gas capacity buildout may maintain the current pattern across regions, mostly likely taking place in relatively wealthy coastal provinces in the Yangtze and Pearl river deltas. Easier access to gas infrastructure is another advantage of these regions over the rest of the provinces. Central coal-rich provinces would need to boost low-carbon energy sources and curb coal under the new climate pledge, but the local governments' fiscal capabilities will constrain their support for costly gas power.

Overall, the outlook for gas consumption and gas power turns brighter with China's recent climate pledge. To reach net-zero emissions by 2060 would require a drastic transformation of China's energy mix, driving up the deployment of low-carbon energy sources. However, the goal to curb fossil energy consumption will then also limit the scope of gas deployment along the pathway. A zero-carbon power system will be based largely on renewables, leaving little room for unabated fossil power generation.

[43] 'Gas 2020 Report', IEA, June 2020, https://www.iea.org/reports/gas-2020/2021-2025-rebound-and-beyond.
[44] 'PetroChina predicts massive Chinese gas demand growth', Petroleum Economist, 20 October 2020, https://www.petroleum-economist.com/articles/politics-economics/asia-pacific/2020/petrochina-predicts-massive-chinese-gas-demand-growth.
[45] Lei Yang, 'Steps towards liberalization of China's natural gas market in the 14th five-year plan', Oxford Energy Forum, September 2020: ISSUE 125.