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China's Dash for Gas: Local Challenges and Global Consequences

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Abstract

China's past energy choices had a significant impact on global markets for coal and oil. China's desire to increase consumption and the recent 2017-18 'dash for gas' captured global attention, but also exposed critical failings in China's gas market. The 2019 lull imposed by the Government reflects the need to address local challenges. This paper analyses the prospects for demand growth and assesses the various ways in which that demand can be met. The critical problem of urban air pollution is the primary motivation for China's current dash for gas, but decarbonisation is a significant co-benefit. The analysis reveals considerable uncertainty surrounding future demand growth. Although China has significant natural gas reserves, they are largely unconventional and present significant geological and technical challenges; domestic production growth is failing to keep pace import dependence is increasing. China's gas imports are met by pipeline gas from Central Asia, Myanmar and, most recently, Russia, and Liquefied Natural Gas (LNG) from a variety of countries, most prominently Australia and Qatar. However, plans to expand Central Asian imports have disappointed and China may agree to develop a second pipeline from Russia or increase its reliance on LNG imports. A 'gas balance model' is used to organise the final discussion and conclusions, which explore possible future developments and their consequences for global gas security.

Keywords: China, natural gas, pipelines, liquefied natural gas, shale gas.

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Introduction

In 2011, the International Energy Agency (IEA) published a special report entitled: *Are We Entering a Golden Age of Gas?* The report “described a future in which natural gas played a more prominent role in meeting the world’s energy needs to 2035” (IEA 2011: 14). The central drivers of their Golden Age of Gas Scenario (GAS Scenario) were twofold: first, that the growth of unconventional gas production, centred on shale gas in the United States and Canada, would ensure a plentiful supply of natural gas at affordable prices; and second, that China would implement an ambitious policy for gas use that would accelerate demand, such that it matches that of the entire European Union in 2035. As we shall see, the Chinese Government has indeed implemented policies to promote natural gas demand; however, progress has been checkered and uncertainties about the future remain. In 2011, China’s gas demand totalled 108.9 billion cubic metres (bcm) and the IEA’s GAS scenario expected that it would reach 247 bcm by 2015; in fact, total demand that year was 194.7 bcm. At the time, there was concern that China’s gas demand was stagnating and that a Golden Age of Gas seemed unlikely (Boersma and Jordaan 2017). Then, stimulated by Government targets, demand grew rapidly. During 2017, China’s gas demand grew by 15.1% and in 2018 by a further 17.7% - such that over the decade from 2007 to 2017 total demand grew by 13% - and in 2018 it reached 283 bcm (BP 2018, 2019). In 2019, as a result of a slowing economy and changing Government policy (China National Gas Development Report (CNGDR) 2019) the rate of growth is slowing to around 10% and a similar rate is now expected during 2020, which would take total demand at the end of 2020 to 342 bcm. The IEA’s GAS scenario projected that China’s gas demand would reach 335 bcm by 2020; thus, it would seem that the recent dash for gas has put China on the path to a golden age. According to the IEA’s GAS scenario, China’s demand will reach 535 bcm by 2030 and 634 bcm by 2035. The latest forecast by the China National Petroleum Corporation (CNPC) puts gas demand in 2035 at 610 bcm and 690 bcm by 2050 (Meidan 2019, 3). By way of comparison, in 2018 the EU’s gas demand totalled 458.5 bcm and the United States 817.1 bcm (BP 2019: 32).

The recent surge in China’s gas demand has caused great excitement and optimism in the global gas industry, but two questions are now being asked: first, will this growth continue, and; second, if so, how will future demand be met? These are matters of global consequence: China’s 2017-18 dash for gas led to a tightening gas market and higher prices for consumers in other gas importing regions, such as Europe. In 2019, the slow-down in China’s gas demand

growth in the face of growing liquefied natural gas (LNG) supply has contributed to a softening of the market and lower prices. Thus, the future role of gas in China is the single most important issue shaping global gas security today. This review paper brings together recent data and analysis to present a critical review of the key drivers that are likely to shape the future role of gas in China. The analysis begins by placing China's energy system in a global context, before then focussing on the role of Government policy in driving gas demand; the paper then turns to sources of supply, focusing first on domestic production, then pipeline gas imports and finally imports of LNG. A simple gas balance model is then used to summarise the key drivers and sources of uncertainty. The conclusions return to the two questions posed above in considering the consequences for global gas security.

China's changing role in the global energy system

There is no doubting that over the last 30 years, and particularly since the turn of the Century, China's rate of economic growth and energy choices have had a global impact. Just consider the statistics. Back in 1990, according to the World Bank's (2019) *World Development Indicators*, China accounted for 21.5% of the world's population, but only 1.7% of its gross national income (GNI in Current US\$); by 2000, the share of world population had fallen slightly to 20.6%, but its share of global GNI had increased to 3.5%. However, after the turn of the Century there was a rapid acceleration in China's economic growth rate, such that by 2018 its share of global GNI was 15.6% (18.6% on a purchasing power parity basis) and it was the second largest economy in the world after the United States (US), but its Gross Domestic Income per capita was only 28.6% of the US level.

China's economic growth has come with a significant increase in energy consumption, and with that carbon emissions. In 1990, China accounted for 8.4% of global primary energy consumption; by 2000, that had risen to 11.9%, and by 2018 its share had reached 23.6%, making it the world's largest energy consumer by some distance (BP 2019; 7). However, over this period, China's economy did show a significant improvement in energy intensity (the ratio between energy consumption and economic output): between 2002 and 2012 its GNI nearly tripled in constant dollar terms, but its energy consumption little more than doubled (Yi-Chong 2016: 192). Vořta (2018: 5) extends this analysis and notes that between 2010 and 2015:

“China’s GDP grew at a rate of 7.8% per year on average, the energy intensity fell by 18.2% (exceeding the national goal of a 16% reduction) and dropped from 0.617 to 0.505 Million tonnes of oil equivalent (Mtoe) per unit of GDP (at 2010 constant price)”. Overall, according to Enerdata (2019): “China’s energy intensity improved by almost 40% between 2000 and 2018, and 2.7% in 2018, driven by energy efficiency policies focused on energy-intensive industries”.

Nevertheless, a combination of an economy dominated by energy intensive manufacturing and a heavy reliance on coal has meant that China’s share of global CO₂ emissions has grown more rapidly, from 7.5% of total CO₂ (excluding Land use and Landcover Change) in 1990, to 11.9% in 2000, reaching 26.8% in 2014, and China is now the world’s largest emitter (World Resources Institute 2018). More recent data from BP (2019) puts China’s share of Global CO₂ at 27.8% in 2018, compared to the US share of 15.2% and the EU’s share of 10.3%. During the decade from 2007 to 2017, China’s emissions grew by an annual average rate of 2.5%, compared to a global average of 1.0% (BP 2019).

The rapid rate of economic growth and associated increase in demand for energy services has led China from being largely energy self-sufficient in the 1990s to the world’s largest energy importer today. As noted above, China accounted for 23.6% of global energy consumption and 34% of global energy consumption growth in 2018 (BP 2019). In fact, 2018 marked China as the largest contributor to global energy demand growth for the 18th consecutive year. That said, China remains a significant energy producer in its own right. The Chinese Government recognises that rapid economic growth has come at significant cost to the environment and public health, the latter in the form of air pollution. It now has a wide range of reforms in place to reduce the economy’s energy intensity – linked to the wider re-balancing of the economy – to improve air quality and to reduce Greenhouse Gas Emissions. According to Climate Action Tracker (2019), the headline targets of China’s Nationally Determined Contribution (NDC) under the Paris Agreement aim to peak CO₂ emissions by 2030 at the latest, increase the non-fossil fuel share in the energy mix to 20% by 2030, and reduce the economy’s wider carbon intensity by 60-65% by 2030 compared to 2005 levels. The problem is that none of the targets promise a physical reduction in emissions, and while there is a strong resolve to reduce reliance on coal, it still accounted for 60.4% of total energy consumption in 2017. Furthermore, coal consumption re-bounded in 2018, growing by 0.9%, although its overall share fell to 58%, the

lowest level on record (BP 2018: 2019). There is evidence that although the Chinese Government took measures in 2016 to restrict the construction of new coal capacity (170 GW of plants were suspended), since 2018 construction has resumed on many coal power stations that were on hold (Shearer et al. 2019: 9). Thus, as will become clear, the current surge in gas demand in China is not sufficient to challenge the premier position of coal; in fact, that is not its intention.

There is no doubting that China's thirst for energy has already impacted on the global coal and oil markets, but until recently the global gas market was relatively untouched by China's demand. However, since 2017, China has experienced record demand growth, adding 31 bcm in 2017 and a further 42.6 bcm in 2018, taking total consumption in 2018 to 283.0 bcm (BP 2019: 34). This 35% increase in China's gas consumption over the two-year period of 2017 and 2018 accounted for 24.6% of total global gas demand growth. The impact on the LNG market has been even more pronounced, with demand growing from 27 bcm in 2015 to 73.5 bcm in 2018, accounting for 49.5% of global LNG demand growth. The IGU (2018: 4) reported that the initial surge in 2017 was the largest annual growth in LNG demand by a single country ever, and it was sufficient to move the average LNG Asian spot price from \$5.28/Million British thermal units (MMBtu) in August 2017 to an average of \$9.88/MMBtu by January 2018. It also resulted in China overtaking South Korea to become the second largest importer of LNG, after Japan (GIIGNL 2018). The demand increase in 2018 was even greater, spurred on by a very cold winter and a hot summer, with the IGU (2019: 11) reporting that China had beaten the record set the previous year by growing at 41%. However, a combination of oil price volatility and LNG supply growth meant that the Japan LNG price averaged \$10.05/MMBtu in 2018 (BP 2019: 35). In 2019, growth continued during the first 7 months, with China importing 45.1 bcm of LNG, up 18.8% on the same period in 2018 (Sharma 2019). However, industry analysts expect the annual rate of growth to slow to 14-17% as a result of slower industrial growth and a relaxation of the policies driving gas demand (as is discussed below). However, due to continued global supply growth and weaker demand, spot prices were significantly lower in 2019, and there was a tendency to fill storage in the summer months in anticipation for winter (when prices are higher). As discussed later, this question of China's future LNG demand is of global consequence, as, in recent years, Europe's access to LNG has been determined by the scale of Asian demand, but market dynamics are changing with significant new supply arriving from Australia, the US and Russia.

As part of a wider rebalancing of the economy, China's energy sector is experiencing a period of significant change. The last decade has seen a steady relative shift in the country's energy mix from coal to gas. In 2015, 64% of China's total energy consumption came from coal (down from 72.4% in 2005), with oil accounting for 18.1% of consumption (17.8% in 2005) and natural gas 5.9% (2.4% in 2005; National Bureau of Statistics 2016). This is part of a general trend of prioritising natural gas and non-fossil fuels (such as nuclear, hydro and renewables) over coal. Nonetheless, China remains the world's largest consumer and producer of coal. That said, the Chinese government has clearly stated its desire for this trend of accelerating gas consumption, while constraining coal, to continue, though the dramatic growth in 2017-18 is unlikely to be repeated. The Energy Development Strategy Action Plan (2014-2020) outlines that non-fossil fuels' share in the energy mix will increase to 15% by 2020 (8.3%-10% for natural gas), with an indicative 20% share by 2030 (the NDC target), and bringing coal's share to under 62% by 2020 (State Council, 2014). The 13th Five-Year Plan (2016-2020) similarly calls for the replacement of coal with gas (and electricity) in non-power sectors (Seligsohn and Hsu 2016). In the middle of this decade, industry experts expected China's natural gas consumption to double from 2015 levels by 2020 (IEA 2015; BP 2016), with China contributing to 38% of global demand growth between 2016 and 2022 (IEA, 2017b). If China sustained a 17% annual growth rate in 2019-20, then it could reach this target, but, as discussed above, an annual growth rate of 10% is expected. In its latest gas market report, which factors in the recent surge in demand, the IEA (2019a: 9) projects that China will account for 40% of global gas demand growth to 2024 but – after record growth of 14.5% in 2017 and 18.1% in 2018 – the annual average growth rate will slow to 8% by 2024 as a result of lower economic growth. The IEA (2019a) also forecasts that by 2024 China's gas demand will total 450 bcm. However, as we explain below, this impressive growth is not guaranteed, as there are many local challenges that might constrain China's current 'dash for gas'.

It is in this global context that this review paper examines the two key questions identified in the introduction: first, what are the future prospects for gas consumption in China, and; second, how will future gas demand be met? This review has gone through a number of iterations that cover events since 2017, which have been fast-moving. The review primarily draws upon in-depth sectoral studies based on desk research – of the academic, government and industry literatures – as a source of statistical materials and secondary analysis. In addition, to gain an understanding of the initial domestic context, interviews were conducted in Beijing and Shanghai in June and July 2017. Interviews were held with representatives from a national oil

company (NOC), two academic experts, and managers at two international oil companies (IOCs) operating in China.

The level of gas demand required by national energy policy

China is now the third largest consumer of natural gas behind the US and Russia (which are also the two largest producers respectively). Prior to the recent surge, years of rapid growth in Chinese gas consumption occurred between 2003 and 2014, termed then by some as the ‘golden age of gas’ (Beveridge and Pun 2017; Raval, 2016), during which time, consumption grew more than five-fold (from 35 to 188 bcm/year; BP 2018). Annual demand growth slowed in 2015 to 4.7% - the lowest since the late-1990s (ibid) - leading some commentators to predict only moderate demand growth over the next decade (Li 2015). Demand grew by a modest 7.7% in 2016 (BP 2017), despite considerable price reductions for industrial and commercial users (discussed subsequently), leading to further speculation that China’s gas demand may be stagnating. In response to this reduced demand, China’s three state oil companies were instructed to decrease domestic production. Production increased by only 1.4% in 2016 over 2015 levels, compared to an average annual growth rate across the preceding decade of 10.3% (BP 2017). As a result, gas imports grew 30% over the same period (from 60 bcm to 75 bcm), thereby increasing China’s import dependency from around 30% to 35% (65% of which was attributable to LNG: IEA, 2017b). Then, as noted above, 2017 saw a renewed surge in demand. This has been explained as a consequence of a cold winter, inadequate pipeline and storage infrastructure, and the need to fulfil, by the end of 2017, the targets of the Government’s 2013 Air Pollution Prevention and Control Action Plan (APPCAP) (IEA 2018: 125; Sandalow et al. 2018: 3). However, according to estimates from China’s National Energy Administration (Meng, 2017), domestic production was similarly expected to jump impressively by 24% in 2017 over 2016 levels, but it only increased by 8.5% (from 137.9 bcm to 149.2 bcm; BP 2018: 28). As a result, import dependence increased further to 37.9% (see Figure 1).

Figure 1 Near Here

In 2017, domestic gas production grew by 9%, but demand grew by 15% (Sandalow et al. 2018). Similarly, in 2018, although domestic production increased by 8.2%, demand grew by 17.7% (BP 2019), resulting in higher levels of imports and growing import dependency. In part, the growing level of import dependence is behind the recent decision by the Chinese

Government to slow the pace of gas demand growth to around 10% (Downs 2019; CNGDR 2019).

Compared to the industrially developed world (i.e. OECD), the share of natural gas in China's total primary energy consumption is modest: 7.4 % in 2018 against an average of 23.8% in the OECD (BP 2019: 9). The policy to increase the use of natural gas is driven, in large part, by the so-called 'Blues Skies' policy: a government mandate to improve air quality and lower CO₂ emissions. This is clear recognition that the rapid industrial growth that the country has enjoyed over the preceding decades has come at a significant cost to the environment and human health. Over the last few years, pollution levels in China's cities have reached record levels. This is significantly attributable to coal-fired plants. Although China's coal-fired power station fleet is relatively young and efficient by global standards, there is a significant number that are over twenty years old and lack the pollution controls of modern plants (Ratner et al. 2016). Furthermore, in many urban areas there is still a widespread use of coal in industry and domestic heating. This has created the political environment for change, which is supplemented by an increasing environmental awareness amongst the country's population (most notably in the country's wealthy and populous coastal regions; Li 2015). Back in 2013, a survey found that 47% of Chinese believed air pollution to be a "very big" problem (Gao, 2015). In 2014, Beijing experienced more than 200 days of "unhealthy" or worse air pollution, including 21 days that were "hazardous", according to data gathered by the city's US Embassy (Gao 2015). Outdoor air pollution was responsible for 1 million deaths in China in 2015, and this is expected to increase to 1.5 million per year by 2040 (IEA 2016). Those living in the country's more coal-dependent North can expect to live five and a half years fewer than their compatriots in the South (Gardner 2014). A recent UN Environment (2019) report documents the progress that has been made over the last 20 years to reduce the level of air pollution in Beijing. It notes that while air pollutants have been lowered by 23-83% (depending on the pollutant) since 2013, the level of pollution still exceeds levels recommended by the World Health Organization. Nevertheless, a combination of policies controlling the use of coal-fired boilers and promoting cleaner fuels, combined with industrial restructuring, has delivered significant improvements.

Additionally, as the largest carbon emitter in the world since 2006, China has faced strong international pressure to reduce its emissions. China ratified the Paris Agreement in September 2016 and outlined its NDC, which, as discussed above, includes pledges to peak CO₂ emissions by 2030 (a target that some experts believe the country will reach by 2025 at the latest; Green

and Stern 2016) and reduce its carbon intensity by 60-65% of 2005 levels by 2030 (McKibbin and Liu 2016). It is important to emphasise, however, that it is an agenda to improve domestic air quality that is currently driving change, with the contribution to global CO₂ abatement a co-benefit. This, coupled with the country's significant coal overcapacity, has seen the recent cancellation of over one hundred new coal plants (Forsythe 2017) and the closure of the oldest, most polluting plants as part of a governmental strategy of gas-for coal substitution in the major urban agglomerations.

In response to mounting pressure from the public, the APPCAP was unveiled in September 2013. The plan focused on improving China's air quality through gas-for-coal substitution, including demand targets for gas and consumption caps for coal. The APPCAP aimed to reduce pollution levels by 15 to 25% between 2013 and 2017 in three key urban regions: Jingjinji in the North and the Pearl River Delta and Yangtze Delta in the South. However, it soon became clear that the primary objectives of ACCAP conflicted with leading drivers of the country's broader policy missions (particularly those related to economic objectives; Wood Mackenzie 2014). As such, the APPCAP has evolved over the subsequent years so as to focus more on managing coal emissions than a widespread transition from coal to gas. Whilst APPCAP remains positive for gas uptake in the country, the policy can be regarded more as pro- 'clean coal' than pro-fuel switching. Nevertheless, the APPCAP has been successful, with several cities meeting their targets by the end of 2015 and air pollution in the three regions now at 70% of 2013 levels (Chun 2017). National initiatives such as the APPACAP are further supplemented by local air quality targets set by Provincial Governments.

As noted above, it was the need to meet targets by the end of 2017 that prompted the recent surge in demand, but the subsequent gas shortages and price spikes also highlighted key weaknesses in the domestic supply chain that might have constrained further demand increases. The response of the Government, as discussed in more detail below, has been to prioritise the construction of new LNG terminal capacity, distribution pipelines and gas storage facilities (see Figure 2), and there is now a plan to unbundle the trunk pipeline network, currently owned by the three NOCs, to create a national gas pipeline network operator (O'Sullivan 2019a; 2019b).

Figure 2 around here

The policy of increasing gas demand at the expense of coal has also been encouraged by pricing reforms, the most notable of which occurred in 2013, following a trial in late 2011. Applicable to pipeline imports and onshore domestic gas production, these reforms replaced the fragmented ‘cost-plus’ approach, which was based on production cost, with ‘city gate’ prices based on average import prices of alternatives (liquefied petroleum gas (LPG) and fuel oil). This effectively moved the pricing point downstream from the wellhead to the city gate terminal (Chen 2014) and enhanced the role of global market mechanisms in determining the levels of gas importation and domestic production. These reforms were outlined in the NEA’s Energy Development Strategic Action Plan 2014-2020 and were aimed at ensuring the sustainable and affordable development of the nascent gas market (Chen 2014). The preceding cost-plus pricing system had discouraged gas importation due to its failure to keep pace with demand dynamics, leading to economic losses for domestic suppliers and supply shortages in several cities (IEA 2017). Prices for supply from offshore and unconventional fields and LNG are unaffected by these reforms and are negotiated independently by the parties involved.

Further reforms in 2014 and 2015 focussed on convergence of the prices paid by residential users to those paid by the industrial and transportation sectors (which had historically been higher by way of subsidising residential consumption). This was thought to be driven by a desire to boost demand for gas in consideration of the country’s ambitious targets for increasing its role in the energy mix, rather than by an agenda of industrial reform (Guo and Chen 2015). Pricing has since proved a valuable tool for stimulating demand, as evidenced by the wholesale price cuts in late 2015 (Ratner et al. 2016), although this does have the disadvantage of discouraging domestic production.

Government reforms have also targeted third party access to LNG terminals, gas pipelines and other infrastructure to enable a diversity of actors to participate in the market. Feng et al. (2019) summarise the current situation thus: “...about half of the gas consumed is allowed to be sold at market prices. From the supply side, the prices of unconventional gas, imported LNG, gas through trading exchanges, and gas sold by storage facilities are no longer regulated”. There is a clear strategy of using price liberalisation to support security of supply. On the demand side, Feng et al. (2019) explain that: “gas sold to direct industrial buyers, chemical fertilizer plants, storage facilities, and gas sold in Fujian Province (as a pilot province) are not regulated”. The net result is that about half of the gas consumed in China is sold at market-based rates. The ultimate goal is to create a market-based pricing system that will reduce the cost to consumer,

whilst also supporting investment in domestic production and infrastructure, which will directly reflect international pricing but also allow for pricing policies (such as seasonal price differentials and interruptible gas prices) to incentivise production gas storage (CNGDR 2019: 27; Daniel 2019: 17).

To gain a better understanding of emerging patterns of consumption, it is helpful to examine the demand behaviour across several key sectors in China. China's gas consumption by sector varies across regions, given that coastal regions have tighter controls on coal use and support gas substitution to a greater extent. However, at the national level, the leading sectors in 2016 were: industry (50%), residential/commercial (18%), power (14%) and transport (11%) (Wainberg et al. 2017). More recent data from the CNGDR (2019: 6) indicates that industry accounted for 38.6% of consumption in 2018, urban gas consumption 33.9%, power generation 17.3%, and the chemical industry 10.2%. Projections from Wood Mackenzie (2016) see the residential/commercial and power sectors catching-up with industry and becoming the largest demand sectors for gas by 2035. The prospects for each of these sectors is considered in brief below.

Industrial demand

The acceleration of China's energy consumption since 2000 is primarily attributed to the growth of its leading energy-intensive industries (such as: extraction of oil and gas; processing of petroleum, coal and nuclear; manufacture of chemical materials/products; smelting and pressing of metals), which now account for over 70% of industrial energy consumption (Li 2015). However, to date, gas-for-coal substitution is only evidenced in small-scale industries. According to Li (2015), broader substitution across China's other industrial sectors faces three opposing factors. First, a supply shortage has been evident in China's gas development since the turn of this century, with surging demand highlighting the inadequacies of domestic infrastructure, and large-scale gas-for-coal substitution would certainly exacerbate this, thereby increasing concerns about import dependence and energy security. These shortages were due to a combination of disappointing domestic production growth and a failure to procure sufficient imports. However, since the experiences of winter 2017/18, there has been significant investment in new import structure, storage and pipelines, and the Government is now confident that current winter demand can be met, although slowing demand growth is also intended to allow the further expansion of critical infrastructures (CHGDR 2019). Second, small-scale industries are a higher priority for substitution as they are typically more energy-

efficient (and thus have a higher capacity for emissions reductions per unit of output). This also illustrates China's focus on carbon intensity targets, as opposed to carbon emissions targets. Finally, the potential capital and operational cost of the substitution remains inhibitive, with gas being more expensive than coal for the same unit of energy. As noted above, this has been caused, in part, by the cross-subsidisation programme that inflates gas prices for industrial users to ensure an artificially low price for residential consumers. The high gas price has even seen a "reverse replacement" of gas with coal in some industrial sectors (Lu and Zhao 2015). This happened again in the winter of 2017/18 in the face of physical shortage of gas that also resulted in higher prices.

Gas-for-oil substitution has also recently been encumbered by low oil prices, with some regions (such as Zhejiang, Jiangsu, Shandong and Fujian) witnessing a reverse switch from gas to oil products (Wood Mackenzie 2016). As international LNG prices in Asia are currently largely indexed to global oil prices and subject to global market conditions, this has introduced a degree of volatility and risk for LNG importers who often find their imports cost significantly higher than domestic prices. This is particularly true of the NOCs, which are locked into a large amount of relatively high-cost LNG imports under long-term contracts. All of this demonstrates just how price sensitive industrial consumers are, and how volatile and unpredictable the domestic gas market is. This is also reflected in the rhetoric of the country's leaders and economic planners, who continue extol the virtues of using more natural gas, whilst also urging caution and slowing growth rates.

Residential demand

Residential consumption has been a priority for gas consumption for a decade. However, the aforementioned pricing subsidies for the residential sector have created an environment of distorted prices and consumers that are just as price sensitive as their industrial counterparts. Price is therefore critical to residential demand, especially as the economy slows and household incomes are squeezed. At the same time, regions across China are distinctive in terms of demand. Northern regions have a lower price elasticity (i.e. a price increase leads to a greater consumption decline) than Southern regions, which is attributed to the availability of coal in Northern China, which offers a substitute for gas when prices are high (Yu et al. 2014). Li (2015) found similar regional variances in demand growth, attributable to each region's 'gas-access-rate' (i.e. the share of the urban population with access to gas), income level (also Yu et al. 2014) and the level of urbanisation. This suggests that with increasing urbanisation in

China comes the potential for growing residential gas demand. Residential gas demand is further encouraged by its relatively low price in comparison to alternative energy sources, such as electricity and LPG (Li 2015), although this beneficial effect was lessened following consumer price increases from PetroChina and China National Offshore Oil Corporation (CNOOC) of around 15% between November 2016 and March 2017 (Sikorski and Tertzakian 2017).

Gas in Power

China has a long-held a reliance on coal for generating electric power, with 67% of all electricity in 2018 coming from coal-fired power plants (BP 2019: 56). As such, the sector is a leading source of CO₂ emissions globally. The role of gas in power generation is currently very low, accounting for only 3.1% of total power generation in 2019 (BP 2019: 54). By comparison, natural gas accounted for 28.4% of electricity production within the OECD in 2016 (BP 2019: 54). Thermal power plants are set to continue their dominance of China's power generation, which Li et al. (2018) attribute to: (i) the comparatively cheap price of coal, which offers little incentive to companies to switch to gas; and (ii) the perception of gas as a transitional solution to the country's air pollution problem, and thus an unwise area in which to make significant infrastructure investments (as it might later result in stranded assets), as opposed to the longer-term solution of low carbon alternatives. However, the country has been steadily incorporating more gas-fired plants into the energy mix, not by way of displacing coal, but rather to meet the growing power demands of the country. The IEA (2019a: 87) reports that in 2018, for the first time, China invested more in Combined-Cycle Gas Turbines than in coal-based power generation. This has occurred most notably in coastal regions, so as to benefit from both nearby LNG terminals and access to the country's gas pipeline network. However, the LNG terminals are not as well integrated into the pipeline system as they might be and LNG is often trucked to consumers, especially in rural areas.

A gas-for-coal switch also addresses the environmental concerns of regional populations, as well as the limited availability of renewable alternatives by the coast (Li, 2015). Gas-for-coal substitution is also supported nationally by feed-in tariffs for gas-fired power and in certain regions by governmental policies limiting the use of coal for power generation. Beijing, for example, shut down its last coal-fired power plant in 2017; a key action behind which is the building of four gas-fired plants to replace that capacity, thereby cutting 10 million tonnes of coal emissions annually (Tan, 2017). Looking ahead, outside of the targeted urban

conurbations, as noted above, the substitution is likely to remain more pronounced in coastal regions due to higher affordability and growing environmental awareness in the burgeoning middle class (Wood Mackenzie 2016). That said, the eventual arrival of substantial amounts of Russian pipeline gas in the early 2020s will offer new supplies that will provide an alternative to coal and challenge the expansion of LNG in this region.

Gas in transport

Transportation is the strongest sector for natural gas growth in China, according the U.S. Energy Information Administration's (EIA) latest projections (a 13.6% average annual percentage change between 2012 and 2040; EIA 2016). The sector is a leading contributor to China's CO₂ emissions: sector-specific emissions more than doubled between 2000 and 2010 and are projected to increase by a further 54% by 2020 from 2010 levels (ICCT 2017). The adoption of natural gas vehicles (NGVs) as an alternative to oil-fuelled vehicles is regarded as a positive step towards reducing these emissions in the coming years in support of meeting the country's emissions targets. Between 2010 and 2015, the number of NGVs in China increased from 1.1 million to 5 million, establishing China as the largest NGV market globally (Peng 2017). A target of 10 million NGVs in China by 2020 was outlined in the 13th Five-Year Plan (FYP). The adoption of natural gas in commercial trucking is thought to be particularly promising, as driven by: (i) governmental policies that support a gas-for-oil substitution; (ii) the competitive cost advantage of gas; and (iii) the relatively low investment costs of the substitution, given that existing oil-fuelled models can be retrofitted (IEA, 2017b). However, widespread adoption of NGVs faces several challenges, including the country's underdeveloped natural gas delivery infrastructure (both pipeline network and fuelling stations), the competitiveness of natural gas compared to oil products, and policies restricting the use of NGVs in the private sector (Wang et al. 2015). This is further challenged by the dominance of partially or fully-electric vehicles ('new energy vehicles', or NEVs) in the government's plans for the national automotive industry, which includes generous subsidies and an ambitious target of reaching seven million annual NEV sales by 2025 (Feng and Clover 2017, Meidan 2019).

Of course, demand varies not only across sectors, but also across regions, as comprehensively addressed by Li (2015), who outlined how regional natural gas demand vary due to a diverse range of factors, including local resource endowment, access to gas supply (i.e. infrastructure), industry structure, income level, urbanisation, competitiveness in comparison with alternative

energy sources, environmental awareness, regional government priorities, and weather (including seasonal variance).

Shell International and China's Development Research Centre (Shell/DRC 2017) conducted a detailed analysis of China's gas development strategies, examining the issues discussed above in great detail. The authors highlight the challenge of trying to position domestic prices: low enough to encourage fuel switching and demand growth whilst at a level that also encourages domestic production and covers the cost of imported natural gas (the latter is determined by global market forces, including the price of oil). Analysis by Li et al. (2018) explores the price elasticity of the gas demand, making clear that the central challenge is making gas cost-competitive in the domestic market. The uncertainty around future gas demand in China highlights the wider challenge facing the global gas industry: to perform a role as a bridge to a low carbon future, gas needs not only to be secure but cost competitive, not just in relation to coal but also renewable alternatives in the power generation sector and electricity in the transportation sector.

The challenge for the Chinese Government lies not only in growing demand in a sustainable and predictable way, but in meeting this demand through stable sources of supply that will ideally limit China's exposure to global gas market volatility and the geopolitical uncertainties that the market raises. Consequently, supply will stem from a mix of domestic production, pipeline imports and LNG imports. Thus, it is important to conceive of China as an 'emergent continental' gas market, potentially similar in scale to the EU or the US, within which there will be significant variations in the relative role of natural gas and the reach of the pipeline infrastructure.

The level of domestic production

Between 2008 and 2018, domestic production of natural gas in China doubled from 80.9 bcm to 161.5 bcm, and China is currently the sixth largest gas producer globally (BP 2019, 32). However, over this period, domestic production failed to keep pace with the country's growing demand for gas (Figure 1); a trend that continues and is predicted to increase in the coming years. Whereas a decade ago China produced more gas than it consumed, in 2018 it imported 37.9% of its gas needs (BP 2019), which could rise to 55% by 2025 (Clemente 2016). The EIA (2016) is more optimistic than the IEA (2018) and predicts that China's gas production will

grow at an average rate of 6% per year to 2040, with much of the increase in the latter years coming from unconventional sources: coalbed methane (CBM), shale and tight gas reservoirs. China currently produces low volumes of CBM and shale gas, and more significant volumes of tight gas. Offshore gas production is modest and, despite having been open to foreign cooperation for decades, it accounts for only 10% of domestic production (Chen 2014). The latest China Natural Gas Development Report (2019) makes clear that it is a national imperative to increase all forms of domestic natural gas production, so as to keep import dependence at a manageable level.

Domestic Gas Production

There is no doubting China's growing inability to meet its domestic gas needs is of concern to the national government (Downs 2019). Regulation in China has been identified as a major constraint to the development of one of the largest gas resource bases in the world (Ratner et al. 2016; Shell/DRC 2017). The 13th FYP outlines the need to increase production of, and encourage private investment in, natural gas through the liberalisation of extraction rights and the reduction of government intervention (including pricing mechanisms; see IEA 2017 and Wang and Qing 2017 for an overview of the 13th FYP in relation to gas). In 2017, Premier Li affirmed that China would reduce barriers to entry to the domestic gas market to enhance private investment, and that private companies would enjoy the same treatment afforded to state-owned companies (State Council 2017).

The 13th FYP indicates an intention for 60% of China's gas needs to be met by domestic production by 2020 (which, at that time, the plan forecasted demand to be 365 bcm). In 2018, domestic consumption was 283.0 bcm and domestic production was 161.5 bcm (and earlier we calculated that 10% demand growth in 2019 and 2020 would take total demand to 342 bcm at the end of 2020). Keeping imports to 40% would require domestic production to be 205.2 bcm: an increase of 27.3% over the next two years when the average annual rate of increase between 2007 and 2017 was 7.9% (BP 2019: 32). The IEA (2019a: 81) predicts that domestic gas production in 2019 will be 171 bcm, rising to 242 bcm by 2024, with an annual growth rate of 7.1%. With China's domestic gas production failing to keep up with demand growth, and with import dependency increasing, the government is left with two choices: reign in demand growth or ramp up domestic production.

Conventional Gas

Conventional natural gas production will be discussed only briefly here, since China is comparatively far richer in unconventional gas. As such, the future of Chinese natural gas production lies with unconventional supplies. Unconventional reserves are listed as an independent resource, thereby permitting investment from private companies; conventional natural gas is not and only the major NOCs are allowed to extract it (Hu and Xu 2013). Conventional production is supported by pricing controls, as discussed in the preceding section, from which unconventional production does not benefit. Growth in conventional gas production has slowed over the last several years and production is expected to peak sometime in the 2020s (Lin and Wang 2012). Unconventional sources are expected to offset this decline, although probably not entirely given the enduring constraints to growth of unconventional production, such as cost and technology.

Unconventional Gas

Development of China's substantial CBM resources, estimated at 36.5 trillion cubic metres (tcm), has been steadily progressing for the last twenty-five years (Li et al. 2018). Initial interest from foreign operators such as BP and Chevron declined in the 1990s due to low production rates, which endure to this day. Following an increase in governmental incentives from 2000 onwards (including loans and subsidies), production from Chinese operators has increased. Over time, this has brought the well costs down, and such activity was further supported by higher natural gas prices (EIA, 2016). Productivity remains a key concern, however, which has been attributed to unfavourable geology (including low permeability and low gas content), the technology level in the field, operations management inefficiencies, personnel experience levels, and well design techniques, amongst others (Lu and Zhao 2015; Mu et al. 2015; Zhu et al. 2015). Overall, development of CBM has been slow in addressing the country's need for natural gas, with 95% of 2014's CBM production focussed in just two basins in the Shanxi Province (Mu et al. 2015). The CNGDR (2019: 8) reports that total CBM production in 2018 was 4.9 bcm, but it is hoped that production can eventually reach 10 bcm (O'Sullivan 2019c, 6).

Shale gas in China has had a similar trajectory to CBM over the past decade. Estimates of China's technically recoverable shale gas are as high as 36 tcm (EIA 2015), although estimates by China's Ministry of Land and Resources are considerably lower at 25.1 tcm (Xiaoli 2014). The EIA projects that shale gas will account for 40% of the country's total natural gas production by 2040, leading it to be the second largest shale producer globally (EIA, 2016).

However, to date, progress has not been as quick as was once anticipated (see: Goa 2012, Sandalow et al. 2014; Jianzhong and Hianzhi, 2017). The 2012 target of 100 bcm/year of combined CBM and shale production by 2020 was reduced to 30 bcm in late 2014 (Ratner et al., 2016). The shale industry did see improvements in 2017 and, according to Wood MacKenzie, nearly 700 new wells will come onstream between 2018 and 2020 at three key projects, all located in the Southwest and representing an investment of \$5.5 billion (Aizhu 2018a). The CNGDR (2019: 8) reports that total shale gas production in 2018 was 10.9 bcm. The IEA (2019b: 80) reports that the combined production targets for PetroChina and Sinopec for 2020 amount to 19 bcm/y, which, whilst almost double the 2018 level, are well short of the Government target of 30 bcm/y. Recognising the current slow rate of progress, the revised targets from the NEA are much more modest with production to reach 80-100 bcm/year by 2030 (Kachkova, 2016).

Several high-profile joint ventures between Chinese and international companies have been established but have proved largely fruitless to date. Chevron have had a partnership with CNPC since 2007 to explore the Sichuan shale basin, although the project has been plagued by costly delays, with production only starting in early-2016. Shell established a production-sharing agreement with CNPC in 2012 but gave up its acreage in 2016 following disappointing production levels due to challenging drilling conditions (Guo and Paton 2016). US-based Noble Energy had a joint venture with Sinopec for several years before selling off its Chinese assets in 2014 (Ratner et al. 2016). Most recently, BP entered into a partnership with CNPC in 2016 that will involve drilling in the same areas ConocoPhillips had previously acquired but later chose not to pursue. This deal reversed what Wood Mackenzie identified as a trend of IOCs relinquishing exploration areas that had been acquired since 2010 (Guo and Paton, 2016). BP have since entered into a joint venture with CNOOC that is focussed on Argentinian shale. The engagement of Chinese companies in joint ventures with IOCs, regardless of their success, has offered an opportunity to gain experience and knowledge that has proven very valuable in bringing down domestic drill costs, thereby increasing the economic viability of Chinese wells (EIA 2016). The potential to transfer advanced drilling technologies to China is also considered a primary motivation for Chinese interest in US shale (Sanati 2010). Meanwhile, Chinese oil and gas equipment companies have been busy reverse-engineering US shale gas equipment, and a domestic supply chain is rapidly developing that is attuned to domestic conditions and will enhance the industry's self-reliance. All of this suggests that a future Chinese shale boom may not provide much of an opportunity for Western investment.

In recent years, development of Chinese shale gas has been supported by government intervention (as with CBM gas development). A four-year subsidy programme was established in 2012 and made available to any Chinese company commercially producing shale gas. The programme was extended in 2015 to 2020, albeit at a falling rate of subsidisation. The decision to reduce subsidisation rates was reported as “a further blow to the nation’s plans to match the US shale revolution” (Hornby 2015). This arrived around the time of the cut to wholesale gas prices, which, as commented in the preceding section, discouraged domestic investment.

It is clear that shale gas is still identified as a potential solution to addressing increased domestic demand without the need for gas imports (EIA 2016). However, a clear regulatory and fiscal framework is yet to be put in place and industry observers have called on policymakers to increase incentives for private investment if high growth in the shale industry is still an aim of the government (Ratner et al. 2016).

Beyond the investment environment in China, many private companies are reticent to commit to Chinese shale whilst concerns around geological complexity, access to water, pipeline and land access, limited infrastructure and a lack of technical expertise remain (Liu et al. 2015; Clemente, 2016). Some have returned the licences that they gained, recognising that they lack the technical competence and financial might to overcome the challenges. There are also concerns about the environmental and social impact of shale gas activity given the current state of regulation in China (Lin 2018). Damaging earthquakes in December 2018 (magnitude 5.7) and January 2019 (magnitude 5.3) in the Sichuan Province that caused injury and destroyed property were probably caused by fracking activities, but do not seem to have impacted on the status of the industry (Lei et al. 2019). It is worth noting that an event of magnitude 2.9 in the United Kingdom gas resulted in an indefinite moratorium on shale gas exploration. Finally, the recent period of low oil prices (and the prospect of the price remaining ‘lower-for-longer’ in the future), in addition to the inflated cost of drilling in China (which remains four-to-five times higher than in the United States despite falling 23% between 2013 and 2015; EIA 2015, Ratner et al. 2016), has also challenged the economic viability of Chinese shale prospects and slowed the pace of development. Nonetheless, the two leading National Oil Companies – PetroChina (CNCP) and Sinopec – continue to increase investment in the Sichuan region and both companies report that they are making significant progress in cutting development costs and improving the efficiency of their hydraulic fracturing technology (Lelyveld 2019). Despite

this, Wood Mackenzie (2019) recently downgraded its long-term expectations for China's shale gas production to 88 bcm, a reduction of 44 bcm over its 2018 view.

The consensus seems to be that China's domestic shale production may reach 13-15 bcm by 2020 (O'Sullivan 2019c: 6). Thus, it seems likely that plans to significantly increase the level of domestic shale gas production will disappoint, in the short-term at least. However, given the capacity of Chinese industry, motivated by the state, to address strategic challenges, it would be wrong to totally rule out a 'Shale Gas Revolution Chinese Style'. Wood Mackenzie (2019) is more upbeat about the prospects for tight gas due to: "more mature technology, reliable geological data and overlapping distribution with conventional gas, which can reduce infrastructure development costs" and it has increased its tight gas outlook to 85 bcm by 2040. Overall, it expects China's domestic production to more than double from 2018 levels to 325 bcm by 2040. When compared to the IEA's (2019a) 'Stated Policies' scenario, which puts China's 2040 gas demand at 655 bcm, this would result in imports accounting for just over half of total consumption, which is not entirely out of line with Government and industry expectations. The question remains, however: where would those imports come from?

The level of pipeline imports secured

China is now the third largest importer of natural gas globally. Until recently, this import demand had been met by roughly equal quantities of LNG and pipeline gas, but in 2018 LNG imports surged ahead: 39.5% pipeline gas to 60.6% LNG (BP, 2019, 38). Figure 3 illustrates the quantities of natural gas imports from pipelines and LNG over recent years. The balance of supply between pipeline gas and LNG sets China apart from other leading importers; Japan and South Korea (LNG only), the United States (mainly pipeline) and Germany (pipeline only). However, until the new pipeline from Russia—the Power of Siberia—reaches capacity in 2025 (assuming demand holds up), it is likely that the share of LNG will continue to increase.

Figure 3 around here

The focus of this section is pipeline imports. Imports of LNG are discussed in the subsequent section.

At present, most of China's natural gas imports arrive via the Central Asia-China pipeline to the North-Eastern province of Xinjiang and, starting in December 2019, from Russia via the Power of Siberia pipeline. An overview of China's current and proposed pipelines is presented in Table 1 below. The leading provider of gas is Turkmenistan; a country in which CNPC is heavily invested. The pipeline from Turkmenistan also runs through Uzbekistan and Kazakhstan, which started supplying natural gas to China in 2012 and 2014 respectively (Ratner et al. 2016). The pipeline is comprised of three lines: Line A became operational in July 2008; Line B, which has a combined capacity with Line A of 30 bcm/y, became operational in December 2009; and Line C, which came online in 2014 with a capacity of 25bcm/year (CNPC 2015). Construction of a Line D began in 2014 and is designed to run from Turkmenistan to China via Uzbekistan, Tajikistan and Kyrgyzstan with a capacity of 30 bcm/y. Having originally been planned to be operational by 2016, construction was indefinitely suspended in early-2017 and the current status of Line-D remains unclear, although it is assumed that it will now be operational by 2022 (IEA 2019b). There are also plans in place to upgrade the compressors on the existing pipelines, which could increase capacity by a further 5 bcm (Daniel 2019: 16), although there remains concerns about the capacity of the Central Asian countries to fill the existing pipes. Whilst the total design capacity of the pipelines from Myanmar and Central Asia is 67 bcm, according to BP (2019, 34) total imports in 2018 were only 47.9 bcm (Turkmenistan 33.3 bcm, Uzbekistan 6.3 bcm, Kazakhstan 5.4 bcm and Myanmar 2.9 bcm), up from 39.bcm in 2017, but only at 73.1% of capacity. This is, however, a significant increase on the 38.0 bcm in 2017 (Espina 2018). The growing unreliability of Turkmen gas supplies, despite the fact that they are required to pay billions of dollars in loans provided by China, explains why the Chinese Government is now seriously considering a second pipeline project with Russia. Most recently, Turkmenistan has agreed to re-establish gas sales to Russia (5.5 bcm a year for 5 years), which further complicates matters (Putz 2019).

Table 1 around here

These issues with Turkmen gas supplies are a blow to China's hopes of increasing pipeline imports so as to decrease its dependency on potentially more volatile LNG imports, which has become a matter of urgency for the Chinese leadership. The leadership has a geopolitical aversion to excessive dependence on LNG that must traverse sea lanes dominated by the US Navy or is sourced from unstable regions of East Africa and the Middle East (Daojong and Sutter 2017). Recent events in the Straits of Hormuz are likely to increase China's anxiety, as

Qatar supplied 17.3% of its LNG imports in 2018. To that mix we can add a desire not to rely on US LNG imports given trade frictions between the two countries. In September 2018, China imposed a 10% tariff on imports of LNG from the US. Although no large-scale agreements have been signed between Chinese and US companies, in 2018 some 33 cargoes were delivered, presumably by portfolio players—companies with multiple sources of supply and multiple customers (Tsafos 2019). Data from BP (2019: 40) details 3.0 bcm of LNG being delivered to China from the US (a 4.1% of imports to China and 10.5% of US exports). In June 2019, China raised the tariff to 25%, and by late August of 2019 only three shipments had been made (Eberhart 2019). For the moment, it would seem that US LNG exporters do not have direct access to China’s LNG market; however, it is likely that LNG would be part of any future trade agreement between China and the US, at which time US LNG exporters may gain privileged access to the Chinese market as a way of balancing trade between the two economies. Such a development would have significant implications for both future gas pipeline projects and the prospects of other LNG suppliers.

When the expansion of the Central Asia-China pipeline capacity stalled, the Chinese government turned to Russia for the supply of pipeline gas. In May 2014, following a decade of negotiations that had failed to reach an agreement, a deal was reached to construct the ‘Power of Siberia’ pipeline at a cost of US\$70 billion to supply 38 bcm/year from Russia’s Far East from late 2019 onwards to Northern China (Wheatley 2015; Paik 2015). The pipeline is part of a thirty-year purchase and sale agreement between the two countries that is reportedly worth US\$400 billion (Charap et al. 2017). The 38 bcm annual volume is equivalent to just over 50% of China’s total gas imports in 2016, and 18% of the country’s total gas consumption. The price of the gas is indexed to the oil price, rather than a European hub price, which means it is beyond Gazprom’s influence. Most of the gas is expected to be consumed in Northern regions of China, where indigenous supply is limited, and demand growth is strong (Wood Mackenzie 2016). However, the construction of a Southern line to Shanghai and Jiangsu creates the opportunity for this gas to reach southern markets during times of modest demand in the North.

The Power of Siberia started operation on December 2, 2019, slightly ahead of schedule, and is expected to deliver 5 bcm of gas in 2020, thereafter ramping up to 38 bcm by 2025. This would surpass Turkmenistan and Australia’s 2018 import levels (33.3 bcm of pipeline gas and 32.1 bcm of LNG, respectively). From the Russian side, it is hoped the pipeline will prove to be the first step in establishing a strategic gas relationship with China, with Russian reserves

being sufficient to support a long-term gas trade of 100 bcm/year (Charap et al. 2017). A second pipeline has also been discussed (the 'Altai' pipeline, or Power of Siberia-2) to deliver a further 30 bcm/year to North-Western China by the mid-2020s. This pipeline would be supplied by existing fields in West Siberia; whereas the Power of Siberia has required the development of new dedicated fields in East Siberia and the Far East. Whilst a non-binding framework agreement was signed in November 2014, a firm contract is still pending and, according to Russian media, the pipeline has been postponed indefinitely (Wood Mackenzie 2016). It is thought this was due to a scaling back of Chinese gas demand projections at the time and disagreements over contracting terms with the would-be operator, Gazprom (Røseth 2017). However, as a result of the recent dash for gas, problems with Turkmenistan and a growing trade war with the United States, there are now signals that the Altai pipeline is in favour again, with President Xi Jinping speaking positively about the project at the Vladivostok East Economic Forum in September of 2018 (Katona 2018). However, there has yet to be agreement on the route of Power of Siberia-2, how it will be financed and the pricing formula (Mammadov 2019). In September 2019, President Putin told the Gazprom CEO, Aleksei Miller, to consider new route options to breathe new life into the project. These include a route via Mongolia, which has been rejected in the past, but would avoid the environmentally sensitive and challenging Altai mountains, although the Mongolia route is longer than the Altai route and would extract a transit fee. There is a third option, the 'Vladivostok' route, which would deliver gas from Sakhalin Island. There is already a pipeline linking Sakhalin to Vladivostok and Gazprom has significant gas reserves offshore of Sakhalin. There is also significant Chinese investment in Novatek's LNG ventures on the Yamal Peninsula. As a result, the potential further expansion of Russia's pipeline and LNG trade with China presents a significant source of competition for others seeking to sell LNG to China (Henderson and Yermakov 2019).

For China, the gas trade with Russia can be viewed quite differently. The relationship is driven as much by geopolitics as economics and is asymmetrically in Beijing's favour as the pipeline trade serves a single market (Røseth 2017). Whilst, the deal cements a strategic allegiance between the countries, and ensures the flow of Russian gas in the event of a conflict with the United States (Daiss 2017), China does not yet 'need' Russian gas in the way that Russia needs a sizeable market for its future exports of pipeline gas, although that may be changing. The trade agreement is an opportunity for China to reduce its dependence on gas imports by sea but achieving this does not require a gas relationship with Russia specifically, and as such China need not compromise on its economic or political interests in order to achieve this (Charap et

al. 2017). Further, China will negotiate prices with Russia from a position of considerable leverage, given the competition Russia will likely face in supplying China's increasingly diversified market (Belyi 2015; Daiss 2017).

Lastly, China has also been importing pipeline gas from Myanmar since October 2013. The Myanmar gas pipeline has a capacity of 12 bcm/year and is connected to the Southern regions of Guangxi and Yunnan in China. The price of the gas transmitted via this pipeline is higher than that imported from Turkmenistan, due to the gas being sourced from an offshore field and the harsh terrain the pipeline crosses en route to China (Chen 2014). The modest capacity of the pipeline means that it plays a limited role in China's total natural gas imports (Xinyu 2015); only 6.1% of total pipeline imports in 2018 (BP 2019). However, the pipeline is a critical supplementary source of supply for the regional market of southwest China.

With the additional capacity of the Power of Siberia pipeline, together with assumption that Line D from Central Asia will start operations in 2022 with a design capacity of 30 bcm, the IEA (2019b: 119) predicts that total pipeline imports will increase from 50 bcm in 2018 to 100 bcm in 2024, which will make China the world's largest pipeline gas importer.

The level of LNG imports required to balance supply and demand

China is now the second largest importer of LNG, behind Japan and just ahead of South Korea. The IEA (2019b: 117) expects China's LNG demand to grow at a rate of 7% year on year, which is actually down 2% on their forecast the year before IEA (2018: 128), reaching 109 bcm in 2024, assuming that LNG import terminal capacity expands sufficiently. This will make China the world's largest LNG importer.

China has clearly learned the lesson from Japan's earlier 'Multiple Sourcing' strategy and has sought to diversify its sources of LNG supply. As noted earlier, China is particularly concerned about managing its dependence on LNG supplies from the Middle East that have to transit choke points at the Straits of Hormuz and Malacca. In 2018, China's LNG was sourced from no fewer than seventeen countries, although over two-thirds of this supply came from two sources: Australia and Qatar (Figure 4).

Figure 4 around here

The surge in imports in 2017, up 42.3%, came on top of significant growth the year before when China's LNG imports rose 33% in 2016 against 2015 levels (GIIGNL 2018). As reported earlier, this trend continued in 2018, when China imported 45 bcm of pipeline gas and 73.5 bcm of LNG (BP 2019, 38). Imports of LNG are focussed particularly on satisfying growing gas demand in coastal regions, where transportation costs are lower relative to pipeline imports and the country's existing infrastructure is already of high capacity. As discussed below, the lack of adequate inter-seasonal gas storage has meant that LNG imports are vital to meeting winter peak demand, and investment in more storage capacity is now a priority (Xin 2019). The critical issue longer-term will be the cost of LNG imports relative to domestic supply and long-term pipeline contracts. In this context, China's growing LNG market power may put it in a strong position to influence how LNG is priced internationally in the future.

Imports of LNG are comprised of long-term contracted volumes that are supplemented by short-term and spot purchases. In both 2015 and 2016, China had more contracted LNG than it could absorb: a position that Rogers (2016) stated could last into the mid-2020s under a low demand scenario, leaving China to mitigate by further postponing the prospective second pipeline in Russia and Line D in Central Asia, and/or by reducing Central Asia volumes. However, that was before the recent demand surge and spot volumes doubled in 2016 compared to 2015 levels, as purchasers took advantage of low prices (Tian 2017). Spot purchases tripled in 2017, increasing their share of total imports from 6% to 18% (IEA 2018, 127). This trend continued in 2018 when spot purchases increased by 75% year-on-year from 10 bcm to 18 bcm, reaching 24% of total LNG imports (IEA 2019b, 118). This is part of a broader trend of increased flexibility in the trade of LNG that is likely to continue as long-term contracts expire and new players (both buyers and sellers) join the marketplace (Ledesma 2016). It is anticipated that this increased flexibility will enable LNG buyers to trade at reasonable prices and lead to the stabilisation of supply and demand, with the diversification of suppliers also enhancing supply security (METI 2016). However, LNG producers rely on long-term contracts to finance investment in new capacity and there is currently a stand-off between producers and consumers over future funding mechanisms (Smedley 2018). Nonetheless, in 2019 there was a record number of new LNG projects announced, many of them targeting anticipated LNG demand growth in China.

LNG Import Infrastructure

China has invested heavily in LNG capacity over the last decade, as reflected in the volumes that are now received. The NEA has underlined a commitment to “vigorously promote” the construction of new LNG terminals and storage facilities (NEA 2014; cited in Ratner et al., 2016). As of mid-2017, there were thirteen terminals in operation with a further six under construction (the latter have a total capacity of 12.5 bcm/y). According to the IGU’s *2019 World LNG Report* (2019: 71), China’s is one of the world’s fastest growing re-gas markets, adding 10.6 million tonnes per annum (mtpa) of capacity in 2018, with a further 37.6 mtpa under construction as of February 2019. In 2018, China’s total import capacity was 64 mtpa (87 bcma); when the projects under construction are completed this will rise to 101.6 mtpa (138.2 bcma). Whilst LNG terminals have been funded by NOCs, some private investment has been made following the liberalisation of the sector in 2014, which permitted private LNG imports, the construction of private LNG terminals and natural gas infrastructure, and open access to existing state-owned terminals (Six and Corbeau 2017). This liberalisation suggests a desire from the government for a more flexible and price-competitive natural gas market (Chen 2014). Numerous private-owned terminals and regasification facilities are currently under various stages of approval and construction.

Expansion of the country’s gas storage capacity is similarly planned. As of 2018, China had 26 facilities with a total storage capacity of 20.0 bcm, and a working capacity of around 10 bcm, which is more than double the capacity back in 2015 (Xin 2019). Nonetheless, this is less than 5% of total gas consumed, compared to 20% in many European countries and 17% in the US where there is a significant swing in demand in winter (Aizhu 2018b). Investment in gas storage has been incentivised by the government since a pricing reform was introduced in October 2016 that allowed gas storage tariffs to be determined by market pricing mechanisms. The 13th Five-Year Plan on Natural Gas Development set a target for underground storage working capacity to reach 14.8 bcm/y by 2020 (Xin 2019). The recent CNGDR (2019) reports that 12 million tons per annum (mtpa) of new storage is planned through 2023.

Terminal utilisation increased from 50% in 2014 and 2015 to 56% in 2016 against a global terminal utilisation of 33-34% in 2014-2016 (IGU 2016; 2017). However, the surge in LNG imports in the winter of 2017/18 stretched some terminals to beyond design capacity. The IEA’s (2018: 128) analysis then showed total operating capacity at 77.4 bcm/y. According to BP (2018), total LNG imports in 2017 were 52.6 bcm, suggesting an overall utilisation rate of 68%, but it was a surge in winter demand that stretched the system. The EIA (2018) reports

that LNG terminals in northern and central regions exceeded their nameplate capacity by 30-40% in December 2017. The IEA (2019a:115) reports that in 2018 almost half (46%) of China's incremental LNG import demand arrived at North Coast terminals and that utilisation rates remain very high at terminals in the North (117%) and East Central (129%) and lower in the South (48%). This also reflects the lack of adequate pipeline capacity to move gas from the south to the north of the country. The numbers from the IGU (2019) (discussed above) suggest that total capacity by the end of 2018 was already 87 bcm/y; the IEA (2019, 117) suggests that the total capacity in 2018 is 92.8 bcm/y. The IGU (2019) estimate that total capacity could reach 138.2 bcm/y when all the projects under construction – both new build and expansion – are completed. Thus, when coupled with an improvement in the pipeline system and expanded domestic storage capacity, the growing size of China's LNG import capacity should place it in a strong position to benefit from the emerging supply glut, which is expected to continue into the 2020s as major export projects in Australia and the United States start up, supplemented in the future by an expansion of Qatari production, as well as new production from Russia, Canada and East Africa.

LNG pricing

Several Asian countries have established regional trading hubs in recent years, so as to increase pricing transparency in a manner that better reflects current market dynamics (Rogers and Stern 2014; EIA 2016, 2017; Fulwood 2018). Given the import dependency of most Asian nations, security of supply often takes priority over competitiveness of pricing, resulting in the so-called 'Asian Premium' (ten Kate et al. 2013). Traditionally, the Asian LNG price was indexed to the oil price, but recently contracts have been signed linked to the US Henry-Hub gas price (H-H) and the Dutch Title Transfer Facility (TTF) price, and there is increasing support for the emergence of an Asian benchmark gas price that would decouple the commodity from the oil price. The introduction of new trading hubs within Asia could, if well connected to one another, bring about healthy competition that supports the establishment of more sophisticated Asian LNG price indices (METI, 2016). Further, regional hubs are a source of flexibility that strengthen a country's supply security (which is decreasing under growing short-term and spot trading) and its ability to respond to external shocks to the energy system (ten Kate et al., 2013).

In China, the Shanghai Petroleum and Natural Gas Exchange (SHPGX) was launched on 1st July 2015, which trades both pipeline and LNG. The hub's strengths lie in its diversified market and gas-on-gas competition, which may offer a more liquid price index than its rivals, together

with the potential future connection with the Sino-Russia pipeline and Pacific market (Paik 2015; EIA 2016). The rewards of such a venture are considerable: the creation of an LNG hub can strengthen the home nation's position in determining and transmitting pricing signals, thereby easing supply-demand adjustments and price arbitration, stabilising procurement and enhancing its leverage in negotiating prices (METI 2016). Establishing the SHPGX as a regional pricing benchmark is particularly important to China given the volumes of pipeline gas anticipated in the coming years. Shi et al. (2016) show that under such a scenario, domestic production would lower spot prices for China (and other key markets), stemming from the competition between LNG and piped gas. The authors also show that this would lead to a reduction in LNG inflows, which would be displaced by the more price-competitive piped gas and greater-incentivised domestic production, thus enhancing the country's supply security. However, the high levels of government intervention (driven by supply security considerations) currently makes SHPGX a less attractive prospect as a regional benchmark than the Asian trading hubs in Singapore and Japan (EIA 2016). Nevertheless, the Shanghai hub allows for domestic demand seasonality to be addressed more effectively and with greater flexibility in supply (Chen 2014). A second Chinese trading hub - the Chongqing Petroleum and Natural Gas Exchange (CQPGX) was inaugurated in January 2017 - and is largely focussed on pipeline gas (Chongqing and the neighbouring Sichuan province benefit from a well-developed pipeline network and diversified gas sources). It is anticipated that the two hubs will support one another in establishing an internationally recognised pricing benchmark. Meanwhile, the so-called Japan-Korea Marker (JKM) is gaining position as an Asian benchmark for spot LNG deliveries, but the growing market power of China, relative to that of Japan and South Korea, will likely influence the future pricing regime for LNG in Asia.

In sum, it is clear that over a relatively short period of time, China has become a major player in the global LNG industry. It will soon pass Japan to become the world's largest importer and it is rapidly expanding its import infrastructure to add greater flexibility. However, barriers remain, particularly in terms of the inter-connectedness of the domestic pipeline system and the lack of adequate storage. No doubt, given time, these problems will be overcome, and the current slowing of demand growth is intended to provide the time for the required infrastructure to be developed. Meanwhile, the global LNG industry is assuming that China's dash for gas will continue and that it will support the current wave of new projects that will come to market in the second half of the 2020s.

Discussion: the future of gas in China

By way of organising this final discussion on the future of gas in China, Figure 5 illustrates China's gas balance and where it sits within the country's total primary energy mix. The focus is on developments to 2030 and their implications for the level and nature of gas imports. On the demand side, growth in consumption in all four key sectors can be expected, to varying degrees, as the Chinese government pursues an agenda of improving domestic air quality. Given the severity of the pollution problem, coupled with the population's demand for action, there is little doubt that this agenda will continue to be pushed into the coming decades. However, as we have seen in 2019, the pace of demand growth will be shaped by Government policy and the wider health of the national economy, particularly industrial growth. Coal dependence is falling within China's energy mix, but we have characterised this less as gas displacing coal and more as gas filling a gap in the country's growing energy demand (as are renewables, increasingly, in power generation). Single-digit demand growth for gas in 2015 and 2016 may have given cause for alarm but growth since 2017 demonstrates that, broadly speaking, the government's policies in support of increasing gas consumption are working. Nevertheless, the surge in demand in 2017-18 served to highlight critical weaknesses in the supporting infrastructure that need to be addressed if growth is to be sustained; specifically, the inadequacy of inter-seasonal storage and the lack of pipeline infrastructure to move gas from coastal LNG terminals.

Figure 5 around here

Uncertainties within the key consumption sectors illustrate several inhibitors to future gas demand growth. First and foremost, price: industrial and residential/commercial consumers in particular have demonstrated a high level of price sensitivity. Whilst pricing reforms have been positive in bolstering demand, price competitiveness against alternatives remains an area of concern; more so in industry, although price increases for residential consumers also challenge the price competitiveness of gas. Both are negatively impacted by any slowdown in economic growth. The power and transport sectors illustrate a further constraint: the perception of gas as 'transitional'. In power, investment in infrastructure is constrained by the notion that low carbon alternatives—renewables—are a longer-term solution and therefore less likely to result in stranded assets. Similarly, the impressive increase in the uptake of NGVs in the transport sector is rivalled by that of NEVs; the two technologies also compete for government support. In the long-term, natural gas uptake will increasingly be challenged in these sectors by low

carbon alternatives, as technologies continue to mature, price per unit comes down, and political priorities shift. Thus, there is still uncertainty over the pace of future demand growth in China, which is determined by the success or failure of state interventions that impact on the price competitiveness of natural gas. The net result is that while growth will continue throughout the 2020s, it be at a modest rate, although in China modest percentages soon turn into impressive absolute increases in demand, and a consensus figure would see China's gas demand reaching 500 bcm by 2030 (remember that the IEA's GAS scenario forecasts 535 bcm in 2030), against a 2020 forecast of 343 bcm. The question then remains, how will that additional demand be satisfied in the 2020s?

On the supply side, a consensus has formed amongst industry commentators—backed by recent performance—that Chinese natural gas demand will increasingly outstrip domestic production in the coming decades, with production likely to fall significantly short of the targets outlined in the 13th FYP. Nevertheless, the potential for the development of the country's unconventional resources remains, though it will take longer to realise. Given the scale of the resources, the decision of the government to open the market and extend incentives to include tight gas is likely to result in both increased investment and increased infrastructure utilisation in the coming years. At present, investment in the country's unconventional resources is constrained by concerns over cost and productivity. The involvement of IOCs in Chinese natural gas (along with the participation of Chinese oil companies in joint ventures in foreign plays) might see improvements to both cost and productivity over time, but at present the IOCs are not engaged in developing China's unconventional gas potential. Two further constraints currently hamper investment. First, whilst market liberalisation is certainly regarded as a positive by the IOCs, they also require clear fiscal, regulatory and pricing frameworks to guide long-term investment decisions: China does not currently have this in place for unconventional plays. Second, oil price volatility and the prospect of oil potentially returning to 'lower for longer' in the face of climate change policy, will see IOCs continue to operate under capital constraints. This will both challenge the economic viability of developing high-cost unconventional plays and enhance the competition for investment between China and other global gas prospects. However, domestic industry is ramping up drilling activity and the development of a supply chain, and while we cannot rule out significant growth in domestic shale gas production, it is likely to be a medium- to long-term prospect.

With regards to China's growing import dependence, there is growing concern on the part of the Government that the failure of domestic production to keep pace with demand is inevitably resulting in rising import dependence. Here, there is significant uncertainty around the balance between imports of pipeline gas versus LNG. With the arrival of gas via the Power of Siberia pipeline, one scenario might see the expansion of capacity within that pipeline—additional compression could take capacity to 50 bcm—followed by agreement on Power of Siberia-2 (either via the Altai or Mongolia) and the final completion of Line D from Central Asia. By the second half of the 2020s this could see total pipeline import capacity reach 180 bcm (see Table 1). Thus, the quantities of LNG required will be determined by the development of domestic production, the price competitiveness of pipeline gas, and the political will to limit seaborne trading (and reliance on US LNG). The IEA's 2019 'Stated Policies Scenario' can give us a possible view of the future, recognising that it is not compliant with the goals of the Paris Agreement. According to that scenario, China's gas demand in 2030 will reach 535 bcm, domestic production will be 250 bcm, making net imports 286 bcm and the level of import dependence 53%. If we assume the upgrading of the three Central Asian pipelines, the completion of Line D and the successful ramp up of Power of Siberia, then in 2025 total pipeline import capacity will be 128 bcm. If there were no further expansion, then LNG imports in 2030 could reach 155 bcm, just over double the imports of 73.5 bcm in 2018 (BP 2019: 40). However, it is possible to conceive of an additional 52 bcm of Russian pipeline gas being available in the second half of the 2020s through the expansion of Power of Siberia-1 and the construction of Power of Siberia-2. This would reduce demand for LNG imports to 103 bcm, which is well below industry expectations. The range of possibilities and level of uncertainty is captured in a recent study by Rogers (2019: 18-19), who projects a high case for China's LNG as 163.4 bcm and low of 132.4 bcm; a difference of 31.0 bcm. A similar study by Cornot-Gandolphe (2019: 34) projects future gas demand in 2030 at 574 bcm, domestic production at 311 bcm, and the range of pipeline imports at 95-155 bcm and LNG imports at 178-213 bcm.

However, this potential pipeline expansion, and the strategic relationships that underpin it, serve another purpose: strengthening China's bargaining power on both pipeline and seaborne trade in the 2020s and beyond as the country pursues an increasingly diversified supply mix. The state of China's gas infrastructure is a final critical consideration. The expansion of inter-seasonal storage and a better-connected pipeline system could dramatically improve the flexibility of China's gas market, enabling it to store significant amounts of gas to meet peak

demand in winter and also move gas around to promote competition between pipeline and LNG imports.

Conclusions: local challenges and global consequences

This final section returns to the two questions posed at the beginning of this review: will China's gas demand continue to grow, and how will future demand be met?

The short answer to the first question is yes, there remains strong policy support for the increased use of natural gas to address environmental concerns, particularly in urban areas. However, the recent dash for gas revealed significant failings in the existing infrastructure and market design. The subsequent lull in late 2019 is recognition by the Chinese Government that a number of local challenges need to be overcome to ensure the orderly growth of gas demand. First, there needs to be further reform to create a market-based system that both incentivises domestic production and delivers gas to consumers at prices that are competitive, whilst returning an acceptable margin to the importers of natural gas. This is no easy task as gas faces stiff competition in domestic energy markets and growing imports expose suppliers to global price volatility. Second, there needs to be continued investment in gas infrastructure. The continued expansion of LNG import terminal capacity is needed to ensure security of supply. Further investment in underground storage facilities is essential to inter-seasonal flexibility, reducing the need for costly LNG imports in the winter months. Finally, alongside the creation of a national pipeline company to guarantee third-party access, there needs to be investment in the domestic pipeline network, particularly in capacity to move gas northwards from the southern LNG import terminals that are under-utilised to markets in the interior and the north where import terminals are overloaded. Failing that, additional pipeline gas imports may be required to serve those markets. Third, the various measures introduced to stimulate domestic gas production need to yield positive results. It is widely recognised that domestic production is failing to keep pace with growing demand and the level of import dependence is growing. This is clearly a concern for the Chinese Government, who may decide to constrain the level of imports in the future or favour the expansion of pipeline gas from Central Asia and Russia over more volatile LNG imports. The net result of these local challenges is that China's gas demand will continue to grow, but at a more modest rate; however, it seems clear that by 2030

China will be a bigger gas market than the European Union and it will be the world's leading importer of pipeline gas and LNG.

The answer to the second question – how will demand be met – is related to the scale and pace of demand growth and the level of domestic production. This review makes clear the level of uncertainty surrounding China's future gas import needs. On the one hand, there is a certain level of pipeline gas imports locked into the system, with a significant expansion due with the ramp-up of the Power of Siberia pipeline to 2025 and the completion of Line-D. Thus, the level of LNG imports will be the residual of total demand, minus domestic production and pipeline imports. The uncertainty increases during the second half of the 2020s. Assuming demand continues to grow at the current more-modest pace and domestic production fails to halt the growing level of import dependence, it is possible to think of two scenarios. One sees the expansion of pipeline imports from Russia with increased capacity on the Power of Siberia, agreement on Power of Siberia-2 and the extension of the Sakhalin-Vladivostok pipeline to northeast China. The total additional capacity would be in the range of 50 bcm, and this would significantly depress LNG imports. The second scenario would limit pipeline expansion to increased capacity on the Power of Siberia and no additional pipeline agreements with Russia. This would result in a significant supply gap to be filled by LNG imports. The global consequences of the two scenarios are quite different and are illustrated by recent events. Following the development of significant new LNG capacity in Australia and the US, the global LNG industry expected a glut as supply outstripped demand in 2016 onwards. Instead, China's 2017-18 dash for gas played a major role in absorbing that anticipated glut. However, the recent slow-down in China's LNG imports is meaning that additional supplies are pushing down prices and the market is not expected to balance until the early 2020s. Despite this, spurred on in large part by the prospect of future Chinese demand, in 2019 a large number of new LNG projects have been sanctioned to come to market in the second half of the 2020s. If the first scenario came to fruition and expanded pipeline imports squeezed China's LNG demand, there would again be a period of over-supply, which would benefit LNG importing countries. If the second scenario were realised and no additional pipeline capacity was built, China would absorb a large amount of the new LNG supply, and tighter markets would mean higher prices for all.

In either scenario, the question remains: whose LNG would Chinese companies buy? This will be a matter of geopolitics as much as economics. At the moment, Australia and Qatar are the

major suppliers and the US is effectively shut out of direct trade. A future China-US trade agreement might see the US gain market share. At the same time, concerns about transit security might constrain imports from Qatar and East Africa. Furthermore, Chinese companies are heavily invested in Russian LNG and also have interests in the west coast of Canada. It is all to play for. What is clear is that China's recent dash for gas has captured the world's attention, but the future of gas in China will require that it overcomes its local challenges before the global consequences become apparent.

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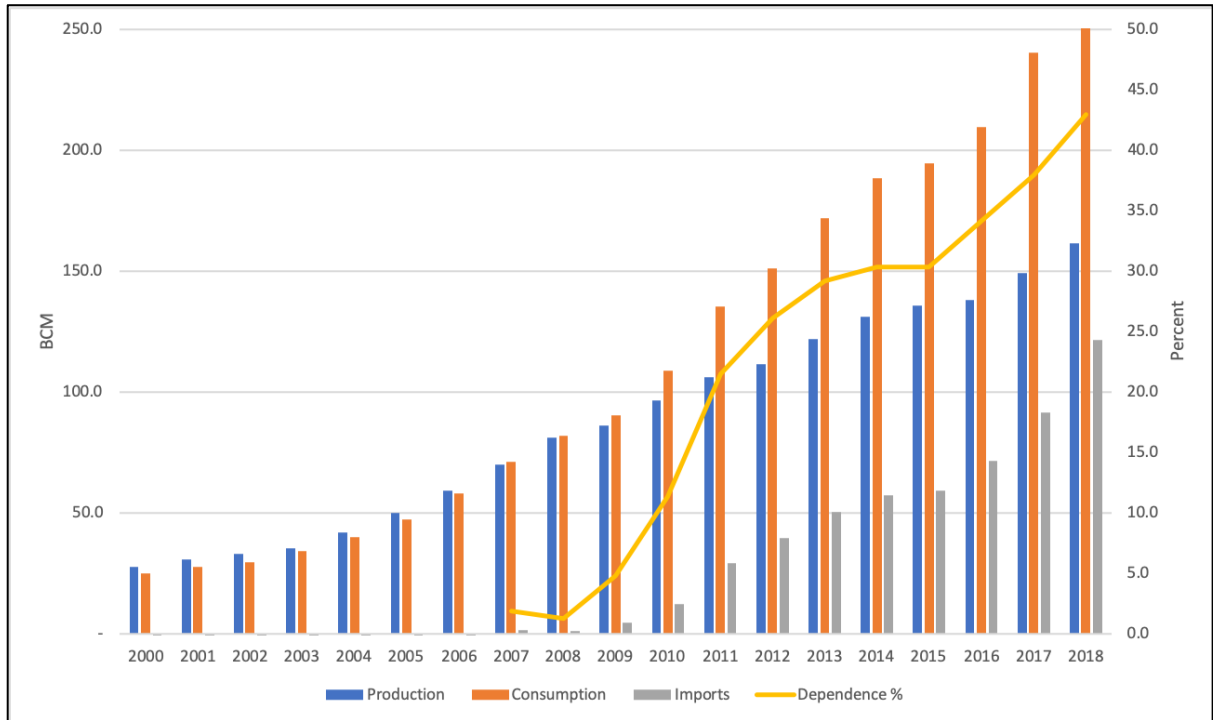


Figure 1: China's Gas Balance 2000-18 (BP, 2019)



Figure 2: China's Natural Gas Resources and Infrastructure Assets
 (Source Ratner et al. 2016)

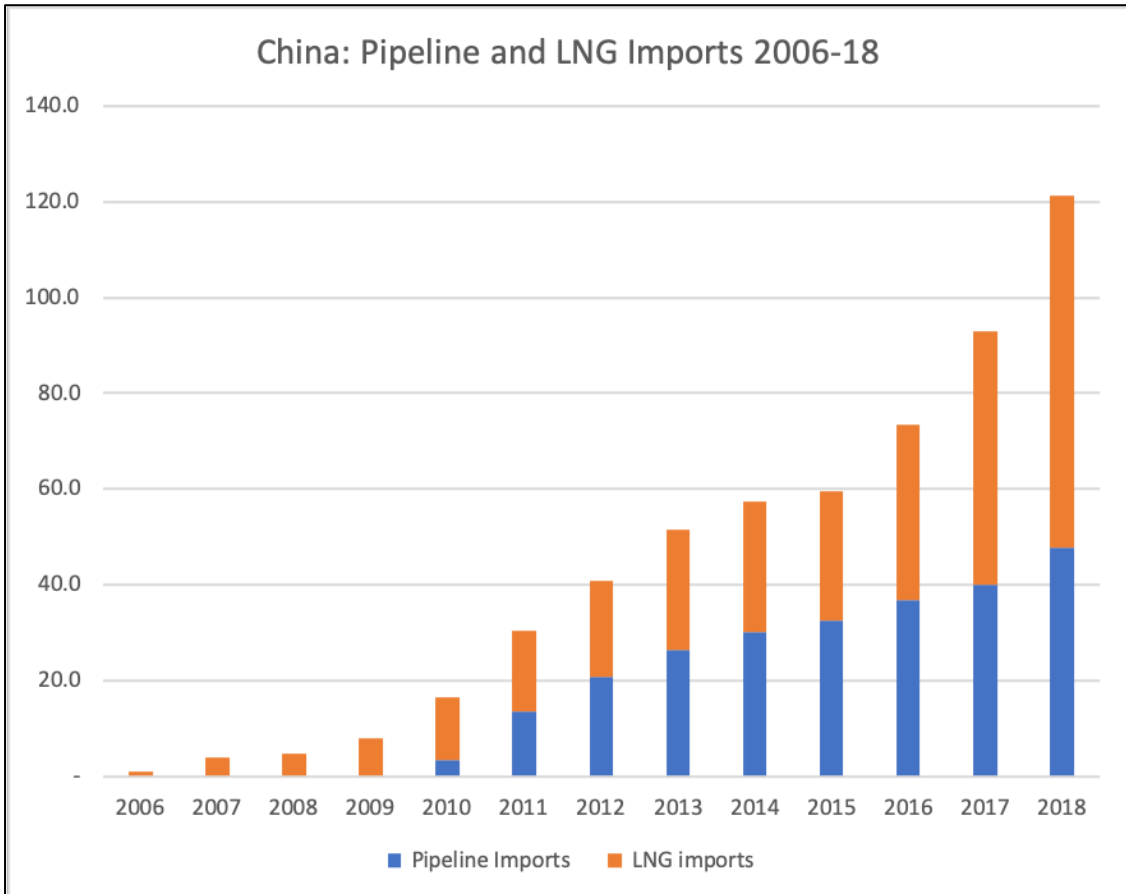


Figure 3: China's Natural Gas Imports 2011-2017 (BP, various years)

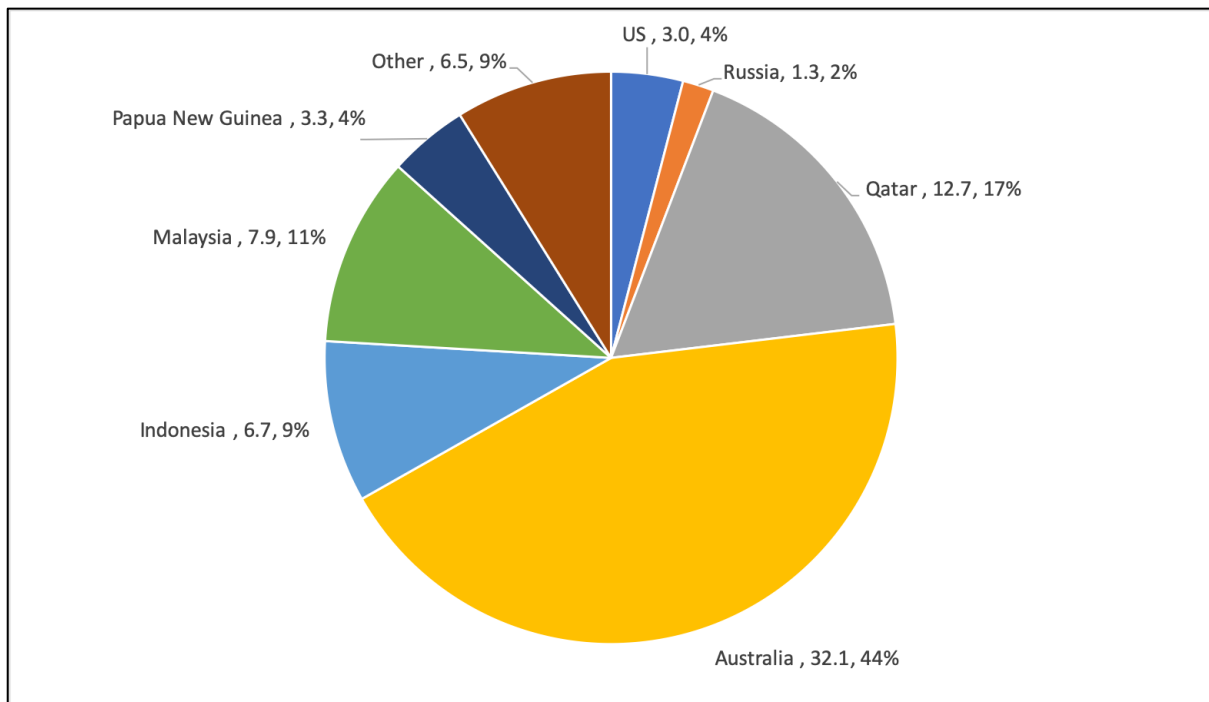


Figure 4: LNG exporters to China in 2018 (data from BP, 2019) - ‘Other’ includes: Algeria, Angola, Egypt, Equatorial Guinea, Nigeria, Norway, Oman, Peru, Trinidad & Tobago, and Yemen, plus some re-directed cargoes from Europe.

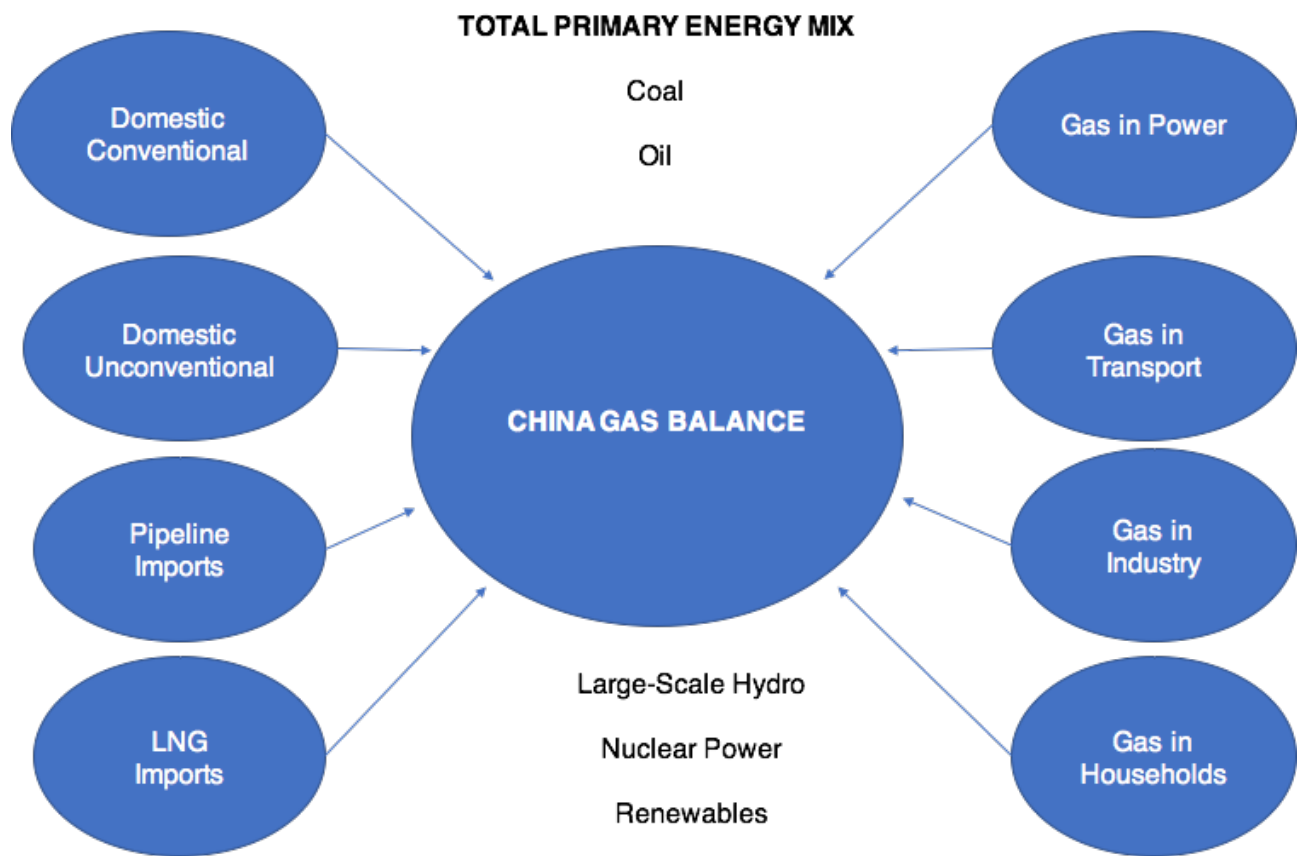


Figure 5: China's Gas Balance Model

Table 1: Current and Proposed Gas Import Pipelines

Source	Project Name	Design Capacity (bcm/year)	Status
Central Asia (Central Asian Gas Pipeline)	Line A	15	In operation
	Line B	15	In operation
	Line C	25	In operation
	Line A – C Upgrade	5	Planned 2020
	Line D	30	Planned for 2022 but currently suspended
Myanmar	China-Myanmar Oil and Gas Pipeline	10	In operation, but with actual sales around 3-4 bcm/y.
Russia	Power of Siberia-1	38 [12]	Completed late 2019 with full supply around 2025, with possible 12 bcm/y expansion.
	Altai (Power of Siberia-2)	30	MOU signed 2014/negotiations suspended

Source: Adapted from Lu and Qi (2018) and Daniel (2019, 16)