

Key Factors Affecting China's Changing Demand for Liquefied Natural Gas (LNG)

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April 2016

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1. Introduction

China's rapid economic growth has brought benefits to its and other economies. However, the activities that underpinned China's economic development have also incurred environmental costs, such as increased emissions of air pollutants, including greenhouse gases.

Structural adjustments are transitioning China's economy from investment-led growth to consumption-led growth. This is leading to lower headline economic growth in China, the elimination of outdated production capacity and relative declines in energy-intensive industries. Heavy industrial sectors have a lower investment share in the economy's gross domestic product (GDP), which implies that China is allocating capital away from these sectors (particularly low value-added activities) towards service sectors and higher value-added manufacturing. This potentially reduces the growth in carbon dioxide (CO₂) emissions and the energy intensity of domestic production.

China's economic transition, climate change policies and anti-air pollution plans have all contributed to the increased use of natural gas relative to other fossil fuels in the economy. The burning of natural gas emits less CO₂ than coal and oil. In this sense, natural gas serves as a key alternative energy source for an economy seeking to achieve a balanced growth path, and implement climate change and anti-air pollution policy reform. However, significant uncertainties arise from the competition between natural gas and non-fossil fuels, and between liquefied natural gas (LNG) imports, pipeline imports and indigenous natural gas production. China is trying to implement an energy transition to lower- and zero-carbon energy choices, and natural gas is viewed as a viable bridge fuel to cleaner energy technologies for at least the next decade (Wang 2015).

China is expected to be a major source of incremental global demand for LNG in the future. By using a dynamic general equilibrium approach, this study investigates how China's aim to increase in natural gas in its primary energy mix to achieve environmental outcomes may affect its LNG imports.

This paper is organised as follows. The second section discusses the energy nexus between economic growth, energy consumption and carbon emissions, and gives an overview of the modelling framework. The third section presents the baseline scenario. Section 4 discusses the policy scenarios and simulation results. Section five summarizes the key findings and concludes the paper.

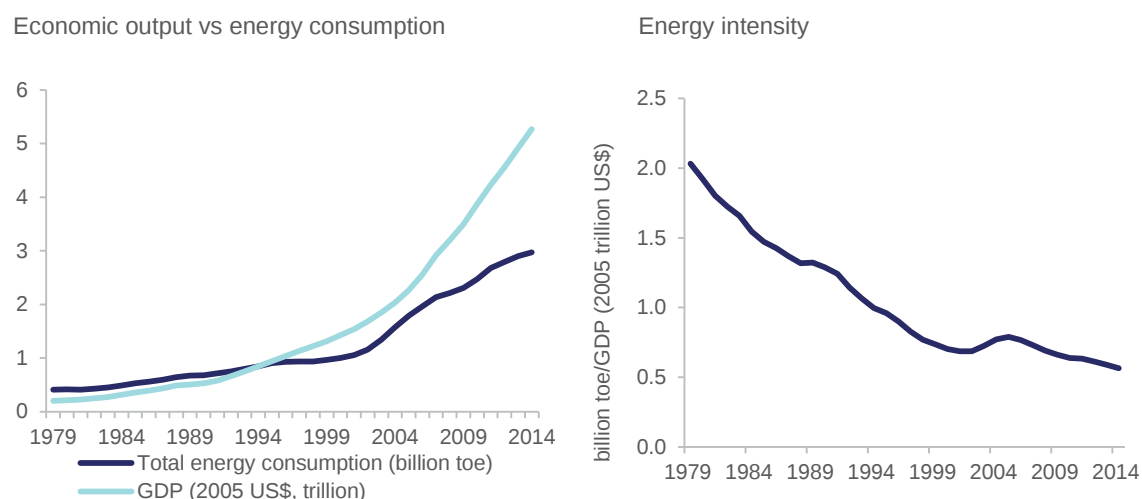
2. Energy nexus and modelling framework

2.1 The nexus between energy, growth and carbon emissions

There is a strong nexus between energy use, economic growth and CO₂ emissions. Using fossil fuel-based energy facilitates economic growth, but it also generates an environmental cost. After a period of rapid economic growth, China is now the largest carbon emitter in the world. China's recent energy policy development focuses on reducing both energy intensity and coal dependency, and increasing the use of cleaner fuels such as gas and renewable energy. Energy intensity is an overall measure of how much energy is used to produce a unit of economic output (i.e. the GDP). The goal for China's sustainable economic growth is to minimise CO₂ emissions and energy cost, and maximise energy security.

Figure 1 shows the levels of economic output, energy consumption and energy intensity in China between 1979 and 2014. In 1979, China's energy consumption was 0.4 billion tonnes of oil equivalent (toe) but, by 1994, this had doubled. It has doubled during each decade since. From 1979 to 2014, China's GDP grew faster than its total energy consumption. As a result, energy intensity has declined significantly. This reflects improved energy efficiencies in industrial production, and a relative decline of energy-intensive activities. Energy intensity halved from 1979 to 1993, and halved again from 1994 to 2014.

Figure 1: China's economic output, energy consumption and energy intensity, 1979–2014

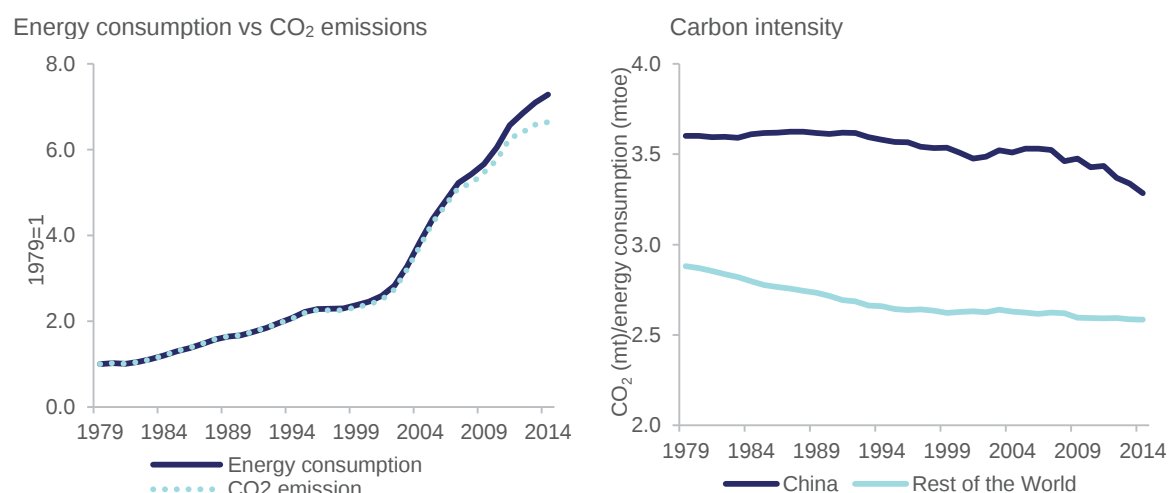


GDP = gross domestic product; toe = tonnes of oil equivalent

Source: BP (2015) and authors' calculations

There is a close relationship between energy usage and CO₂ emissions. Energy consumption and CO₂ emissions have been growing steadily since China's economic reforms commenced in 1979. However, during the past 5 years, the trends in CO₂ emissions and energy consumption have diverged. Energy consumption has increased while carbon intensity has decreased.¹ Despite this recent development, China's carbon intensity is still higher than the rest of world (see Figure 2).

Figure 2: Nexus between energy consumption and CO₂ emissions in China, 1979–2014



CO₂ = carbon dioxide; mt = metric tonne; mtoe = million tonnes of oil equivalent

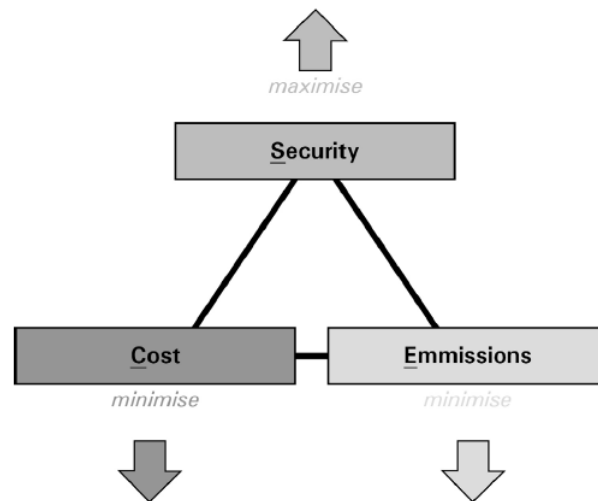
Source: BP (2015) and authors' calculation

¹Carbon intensity is the amount of carbon dioxide generated (in metric tonnes) per unit of energy consumed (in million tonnes of oil equivalent).

2.2 Energy policy development

China's policy makers are facing challenging trade-offs between energy security, cost and environmental outcomes, particularly CO₂ emissions reductions (see Figure 3 — the 'energy policy trilemma') (Wensley et al. 2013). The energy policy trilemma describes the challenge for an economy to simultaneously achieve energy security, access to affordable energy service, and environmentally sensitive production and use.²

Figure 3: Energy policy trilemma



Source: Wensley et al. (2013)

The World Energy Council publishes an Energy Trilemma Index that ranks countries in terms of their likely ability to provide sustainable energy policies. Countries are scored based on the three dimensions of the energy trilemma:

- Energy security. The effective management of primary energy supply from both domestic and external sources, the reliability of energy infrastructure, and the ability of participating energy firms to meet current and future demand.
- Energy equity. The accessibility and affordability of energy supply across the population.
- Environmental sustainability. The achievement of supply- and demand-side energy efficiencies, and the development of energy supply from renewable and other low-carbon sources.

On the Energy Trilemma Index, China is ranked 129th in the world for environmental impact mitigation, 79th for energy equity and 21st for energy security. Table 1 shows that China's energy security is relatively strong, but environmental sustainability remains a challenge for China's rising energy demand.

²<https://www.worldenergy.org/work-programme/strategic-insight/assessment-of-energy-climate-change-policy/>

Table 1: Energy Trilemma Index, rank for selected countries, 2015

Country	Total rank	Energy security	Energy equity	Environmental mitigation
India	107	53	104	122
China	74	21	79	129
Brazil	37	43	78	17
Japan	32	83	19	49
Australia	17	6	14	110
Germany	13	25	46	44
United States	12	3	1	95
Canada	7	1	2	71

Source: World Energy Council (2015)

China's recently developed energy policies are focused on mitigating the environmental impact of air pollution and climate change. In 2014, the Chinese government announced strengthened national action to address these issues.

Under the *2014–20 plan on upgrading and reforming energy saving and emissions reduction in coal-fired electricity generation* (NDRC 2014a), the share of coal in Chinese primary energy consumption is targeted to fall below 62 per cent by 2020 — down from 66 per cent in 2013. New standards have been set for coal-power generation fleets, so that 28 per cent of coal-fired electricity generation should be combined heat and power (CHP) by 2020. Coal power plants with a capacity of more than 600 megawatts (MW) are required to achieve the efficiency target of 300 g of coal equivalent per kilowatt hours (kWh) by 2020. Any new development of coal-fired power plants will no longer be approved in the major population centres of Beijing, Tianjin, the Yangtze River Delta, and Pearl River Delta regions, unless implemented with CHP. Beijing has announced that it will replace all coal-fired power with natural gas plants.

The energy development strategic action plan 2014–20 (State Council of the People's Republic of China 2014) reiterates the aim of the 12th Five-Year Plan to cap China's primary energy consumption at 4.8 billion tonnes of standard coal equivalent per year by 2020. To achieve this, annual coal consumption will be held at 4.2 billion tonnes until 2020 (approximately 16 per cent above 2014 levels). The use of natural gas is expected to expand to about 10 per cent of primary energy consumption — in part by replacing coal in cooking and using heavier fuels for transportation. This gas objective will be supported by increased conventional and unconventional resource exploration and a target for pipeline infrastructure to total 120,000 km by 2020.

The *2014–20 national plan on climate change* (NDRC 2014b) aims for a 40–45 per cent cut from 2005 levels in CO₂ emissions per unit of GDP by 2020. Industry will play a major role in reducing emissions. Industry is expected to cut emissions by about 50 per cent per unit of GDP, and total CO₂ emissions from the steel and cement sectors are expected to stabilise at 2015 levels by 2020. The share of non-fossil fuels in primary energy consumption should reach 15 per cent by 2020, which will require approximately 190 terrawatt hours (TWh) of renewable and nuclear power generation per year until 2020.

On 30 June 2015, China submitted its Intended Nationally Determined Contribution. China aims for carbon emissions to peak within 15 years, and to employ its best efforts to achieve that outcome. China proposed:

- a peak in carbon emissions by 2030, at the latest

- a continued reduction in carbon intensity, targeting a 60–65 per cent fall in the economy’s emission intensity by 2030 relative to 2005 levels (or conversely, increasing the amount of economic output per tonne of carbon by almost two-thirds)
- an increase in non-fossil energy sources to represent at least 20 per cent of total primary energy use by 2030.

China also plans to start its national emissions trading system in 2017, which covers key industries such as iron and steel, power generation, chemicals, building materials, paper making, and non-ferrous metals. China has also committed to promote low-carbon buildings and transportation. By 2020, China’s goal is to have 50 per cent of newly built buildings be ‘green’ in cities and towns, and 30 per cent of motorised travel be on public transport in big- and medium-sized cities. It will finalise the next stage of fuel-efficiency standards for heavy-duty vehicles in 2016, and implement them in 2019.

2.3 Modelling framework

In this paper, we use a dynamic CGE model of Chinese economy - CHINAGEM model to explore and analyse China’s energy policy issues. The standard CHINAGEM model includes 137 sectors. But in this paper we incorporated a climate change module which include energy accounting and carbon emission accounting into CHINAGEM model. The extended CHINAGEM model includes 143 sectors with 2007 input-output table. The core CGE structure of CHINAGEM is based on ORANI, a static CGE model of the Australian economy (Dixon et al 1982). The dynamic mechanism of CHINAGEM is based on the MONASH model of the Australian economy (Dixon and Rimmer, 2002). The CHINAGEM model captures three types of dynamic links: physical capital accumulation; financial asset/liability accumulation; and lagged adjustment processes in the labour market.

The old version of CHINAGEM models lacks the capacity to model energy issues in detail. Primary energy is supplied by only two industries: the coal industry, and a crude oil and gas industry. There are two secondary energy industries, which produce refined oil products and electricity. For the purpose of this study, we further modified the CHINAGEM model by:

- splitting the crude oil and gas industry into the crude oil industry and the gas industry
- disaggregating domestic gas production into conventional and unconventional gas production
- separating two sources of imported natural gas — pipeline gas and LNG
- disaggregating electricity generation across six unique fuel technologies – coal, gas, oil, nuclear, hydro and other renewables — and introducing inter-fuel substitution in electricity generation
- defining cost-responsive changes in the relative supplies of conventional and unconventional gas
- defining price-responsive substitution possibilities in demand for the two alternative sources of imported gas supply

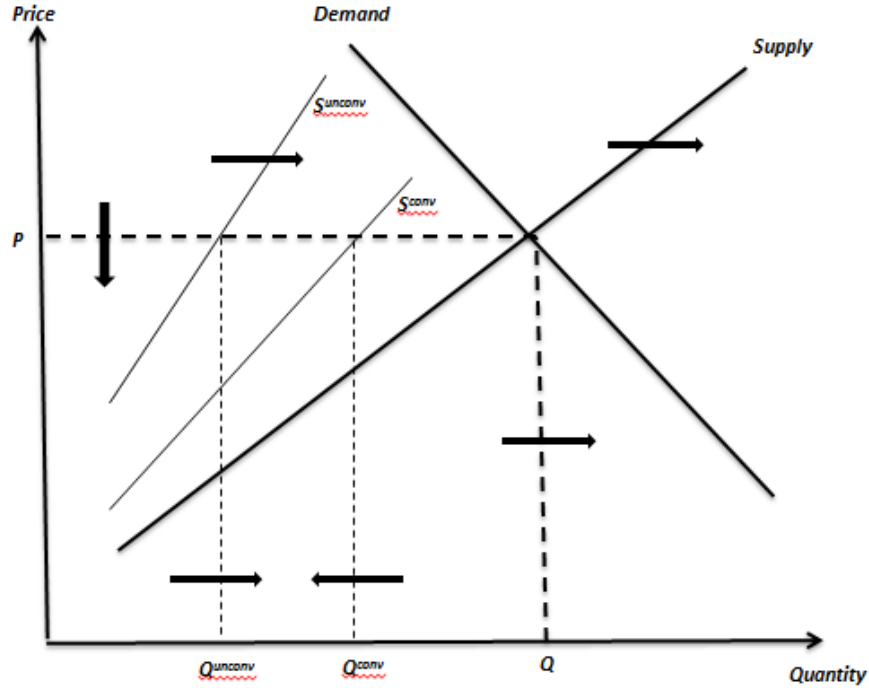
2.3.1 Disaggregation of oil and gas

The initial database recognised crude oil and gas production as a single industry producing a single product. We separate this industry into three parts: crude oil, conventional gas and unconventional gas. We separate the single commodity into crude oil and gas. The crude oil industry produces only crude oil and is the only domestic industry that does so. The two gas industries each produce a single product (gas) and are the only domestic industries that do so. Oil and gas are also imported. Total supply of each commodity equals their domestic production plus imports.

2.3.2 Cost-responsive changes in relative supplies of conventional and unconventional gas

By introducing a two-industry structure for gas supply, we provide the model with the means for cost-responsive changes in relative supplies. This is illustrated in Figure 3.

Figure 3: Cost-responsive changes in relative supplies of conventional and unconventional gas



Initially, the intersection of market supply and demand determines an overall quantity of gas supplied (Q) to match demand at the market price (P). At this price, the amount of unconventional gas supplied is Q^{unconv} and the amount of conventional gas supplied is Q^{conv} . Now, suppose that there is a cost-reducing change in technology for producing unconventional gas. As shown in the diagram, this shifts the supply schedule for unconventional gas to the right. With the supply schedule for conventional gas unchanged, there will be a shift out in market supply. With the market demand schedule unchanged, this leads to a lower market price and increased overall supply. The share of unconventional gas in total supply rises and the share of conventional gas falls.

2.3.3 Two sources of supply of gas imports

China's demand for gas is met from domestic production and imports. As explained above, domestic gas is supplied from conventional and unconventional producers. There are two primary sources of import supply: pipeline gas and shipments of LNG.

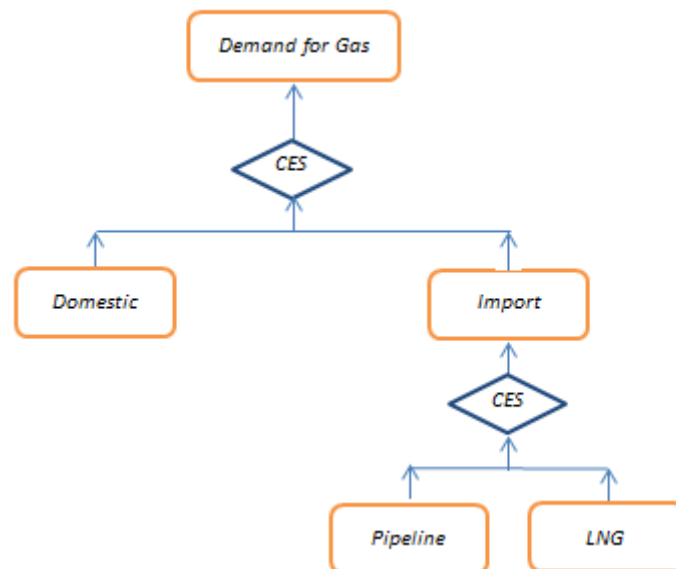
To model two sources of gas supply, we require data on expenditure by source of supply for each gas user recognised in the model. Currently, these data for individual users are not available. Accordingly, we use national shares to allocate purchases of imported gas of each user to pipeline and LNG sources.

To model the alternative sources of imported gas, we assume that pipeline gas is an imperfect substitute for LNG. Thus, the landed cost, insurance and freight (CIF) price of pipeline gas can differ from the landed CIF price of LNG, and that any change in the relative price will lead to a change in ratio of use. This is illustrated in Figure 4, which shows the input structure for gas for a typical gas user in the model. At the top level, overall demand

for gas is met from a combination of domestically produced gas and imported gas. The aggregator function has a CES form. As explained above, domestic gas can be sourced from conventional and unconventional producers.

The idea that domestically produced gas is an imperfect substitute for imported gas is part of the existing model structure. To this we add the new specification that allows for imported gas to be sourced from LNG and pipeline gas. Again, the aggregator has a CES form.

Figure 4: Demand for gas from alternative imported sources



CES = constant elasticity of substitution

2.3.4 Electricity disaggregated by generation type and supply

The current CHINAGEM model recognises one electricity sector that generates electricity, and provides services associated with transmission, distribution and retailing. Intermediate inputs to electricity, including fuels, are combined in fixed proportions. Accordingly, there is no possibility of inter-fuel substitution in electricity generation.

We correct this by introducing inter-fuel substitution in electricity generation using the ‘technology bundle’ approach. In the revised model, we split the composite electricity sector into generation and supply. Electricity-generating industries are distinguished based on the type of fuel used. The end-use supplier (electricity supply) purchases generation and provides electricity to electricity users. In purchasing electricity, it can substitute between the different generation technologies in response to changes in generation costs. Such substitution is price induced, with the elasticity of substitution between the technologies typically set at five.

The model distinguishes six types of electricity generation. Coal, oil and gas use fossil fuels, whereas nuclear, hydro and other rely on renewable energy sources. It treats each type of electricity generation as one industry with a unique output, such that electricity produced by different fuels may, and indeed are likely, to have different prices in different scenarios. All electricity generation industries sell only to the electricity supply industry. The electricity supply industry sources from these electricity generation industries according to a CES substitution. In configuration, we set the value of this substitution variable to be 5. (If the value of the substitution variable is 0, then effectively setting the production structure would be Leontief. This reflects the fact that the dispatching order in China’s electricity market reacts more to administrative orders than price signals.)

3. Baseline Scenario

The baseline forecast is a business-as-usual scenario for the Chinese economy for the period 2014 to 2030. It is constructed on the assumption that there will be no changes in government policies, beyond those already announced. More specifically, for the macro variables, the baseline is developed under the assumptions that: (1) the Chinese economy will continue to grow strongly, but following recent trends, overall growth will slowly diminish; (2) the pattern of growth will favour consumption and consumption-related industries at the expense of investment and investment-related industries; (3) import growth will exceed export growth; and (4) growth in service sectors will exceed growth in industrial sectors. Table 2 shows the calibrated growth rates of GDP components in the baseline scenario. These numbers are used as inputs to CHINAGEM under the forecast closure, yielding the assumed growth of real GDP for the forecast simulation from 2014 to 2030.

Table 2: Forecast simulation: growth rates of real GDP and GDP components, 2014–30 (per cent)

GDP component	Average annual growth rate				
	2014	2015–16	2017–20	2021–25	2026–30
Real consumption	8.84	8.37	7.79	7.22	6.64
Real investment	7.10	6.72	6.25	5.79	5.33
Government expenditure	7.70	7.29	6.79	6.28	5.79
Export	8.17	7.73	7.20	6.67	6.14
Import	10.15	9.60	8.94	8.28	7.62
Real GDP	7.40	7.00	6.50	6.00	5.50

GDP = gross domestic product

Source: Authors' calculations

Table 3 displays the growth rates of value added by industry groups during the 2014–30 forecast period. The growth of agriculture (as a whole) is assumed to follow its historical trend, such that growth is slower than that of the industry and service groups. As assumed, the service group grows faster than the industry group beyond 2015.

Table 3: Forecast simulation: growth rates of value added by industry group, 2014–30 (per cent)

Industry group	Average annual growth rate				
	2014	2015–16	2017–20	2021–25	2026–30
Agriculture	3.87	3.88	3.73	3.57	3.40
Industry	8.00	7.61	7.31	7.00	6.68
Service	7.59	8.01	7.70	7.38	7.04
Real GDP	7.40	7.00	6.50	6.00	5.50

GDP = gross domestic product

Source: Authors' calculations

Based on information from the United Nations' (UN) medium variant population projection, Table 3 shows the growth of population for the forecast period. For employment, as assumed, the labour force participation rate and unemployment rate from 2015 to 2030 will be the same as in 2014, so we can take the growth of employment to be the same as that of the working age population, as derived from the UN population projection.

The overall population growth rate will, however, trend lower than the historically observed growth rate (Table 4), which is driven primarily by a continuing trend of declining fertility rates. In addition, the size of the population aged 65 and over is projected to increase dramatically, from 116 million in 2010 to an estimated 250 million in 2030 (UN 2012). When combined with reduced rates of fertility, this points to a strong decline in the proportion of the Chinese population that are of working age (15 to 65 years) during the forecast period.

In this context, continued expansion of the capital stock (as a result of strong growth in investment) and ongoing improvements in primary factor augmenting productivity will be the key drivers of China's economic growth during the forecast period.

Table 4: Forecast simulation: growth rates of employment and population, and GDP deflator and import price index, 2014–30 (per cent)

Component	Average annual growth rate			
	2014	2015–19	2020–24	2025–30
Employment	0.35	–0.21	–0.04	–0.29
Population	0.42	0.44	0.22	0.06
GDP deflator	2.00	2.00	2.00	2.00
Import price index	1.00	1.00	1.00	1.00

GDP = gross domestic product

Source: Employment and population data are from UN (2012), GDP deflator data are from WDI online. The change of GDP deflator and import price index are authors' assumptions.

For the key energy and industry assumption in the baseline scenario, we use the IEA's Current Policies Scenario from its World Energy Outlook 2015, which comprises a suite of cross-cutting policies³, power-sector policies and industry-sector policies (see Table 5). Other assumptions, such as lower growth for steel production and higher efficiencies in metallurgical coking operations, are also included in Table 5.

³ Cross-cutting policies refer to policies that have multiple impacts

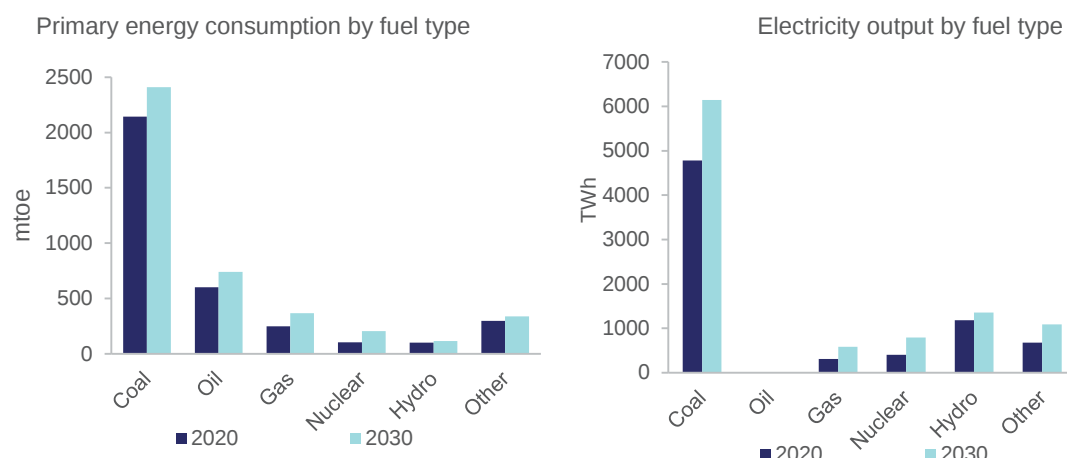
Table 5: Key energy and industry assumptions/scenarios for baseline forecasts

<i>Cross-cutting policy assumptions by scenario</i>	<i>Power-sector policies and measures by scenario</i>	<i>Industry-sector policies and measures by scenario</i>
Implementation of measures in the 12th Five-Year Plan, including a 17 per cent cut in CO₂ intensity by 2015 and a 16 per cent reduction in energy intensity by 2015 compared with 2010. Increase the share of non-fossil fuels in primary energy consumption to around 15 per cent by 2020.	Implementation of measures in the 12th Five-Year Plan. 290 GW of installed hydro capacity by 2015. 100 GW of installed wind capacity by 2015. 35 GW of installed solar capacity by 2015.	Small plant closures and the phasing out of outdated production, including the comprehensive control of small coal-fired boilers. Mandatory adoption of coke dry-quenching and top-pressure turbines in new iron and steel plants. Support of non-blast furnace iron making. Three industries — iron smelting, steel making and steel rolling are assumed to grow at 3 per cent in 2015, 2 per cent in 2016, 1.5 per cent in 2017, 1 per cent in 2018 and 0.5 in 2019 and 0 per cent from 2020 onwards. Due to small plant closures and the phasing out of older technologies, steel making in China will become more efficient in its use of coke. It is assumed that in every year steel producers will reduce their use of coke relative to output by 5 per cent.

CO₂ = carbon dioxide; GW = gigawatt

According to the IEA's current policy scenario (2015c), China's coal consumption is project to increase from 2,144 mtoe in 2020 to 2,410 mtoe in 2030 (see Figure 5) and the share of coal in primary energy mix will decline from 61.2 per cent in 2020 to 57.5 per cent in 2030. the share of gas in the primary energy mix will increase from 7.2 per cent in 2020 to 8.8 per cent in 2030

Figure 5: Forecasted primary energy consumption and mix by fuel type based on the International Energy's Agencies scenarios for China's current policies



mtoe = million tonnes of oil equivalent; TWh = terawatt hours

Note: The Current Policies Scenario assumes no changes in policies from the mid-point of the year of publication (i.e. from about June).

Source: IEA (2015c)

4. Policy Scenarios and simulation results

4.1 Policy scenarios

We designed four policy scenarios. The aim of a policy simulation is to explore how the economy would evolve when subjected to various shocks or changes in economic policy, relative to the baseline (forecast) simulation.

- Policy scenario one — increasing the share of the service sector

Policy scenario one models an increase of the share of the service sector in the GDP. This is done by accelerating economic restructuring, coupled with increases in household consumption of services, more urbanisation and preferences towards cleaner fuels such as gas. Specifically, it is assumed that the share of the service sector in GDP will be about 5 per cent higher in 2030 than in the baseline scenario (see Table 6).

To achieve this, the service sector's share is treated as an exogenous variable, which frees up the average propensity to consume (APC). Thus, the model determines changes in the APC, which are consistent with the exogenously imposed increases in the service share.⁴

The additional assumptions for scenario one include:

- Household preferences will shift towards service goods at 5 per cent each year. As Chinese consumers become wealthier, they will spend more money on service products such as education, communication, travel and finance. Note that the shift in preferences means that, if

⁴ By making a variable endogenous, the model is now free to determine the appropriate values for the variable within the modelling framework.

prices and income remain at baseline values, then Chinese consumers will increase the share of service in their overall budget by 5 per cent per year.⁵

- Household preference for coal will be 13 per cent lower each year than baseline. The rationale for this assumption is
 - as incomes rise, households will choose to consume cleaner energy — that is, gas rather than coal
 - rapid urbanisation means that more people will live in the city where people normally consume more gas than coal. The calibration of the shock is based on a subjective judgement that urbanisation will reduce household consumption of coal by 2030, by around 80 per cent compared with baseline levels.⁶

Table 6: Changes in different sectors' contribution to gross domestic product

Year	Agriculture		Industry		Service	
	Baseline	Policy one	Baseline	Policy one	Baseline	Policy one
2015	9.0	8.9	45.8	45.8	45.2	45.3
2020	7.7	7.2	44.6	43.7	47.7	49.2
2025	6.6	5.7	42.9	40.6	50.6	53.7
2030	5.6	4.5	40.7	36.9	53.7	58.6

Source: World Bank (2012) and authors' assumptions

- **Policy scenario two — capping coal consumption by 2020**

Policy scenario two reduces the share of coal in primary energy consumption is achieved by capping coal consumption (i.e. peak coal) to a maximum of 4.2 billion tonnes in 2020. This results in a reduction in the coal share of the energy and electricity mix, and the CO₂ intensity (i.e. CO₂ emissions per unit of GDP). To this end, it is assumed that:

- the growth rate of primary coal consumption will gradually decline from 2015, and will be zero from 2021
- electricity efficiency will be 1.5 per cent higher each year than under the baseline scenario.

- **Policy scenario three — higher unconventional gas production**

Policy scenario three targets an increase in unconventional gas production using the IEA New Policies Scenario for China as a guide (IEA 2015c). This will be done by increasing overall natural gas supply by attracting both foreign direct investment (FDI) and domestic investments in gas infrastructure, and unconventional gas exploration and production.

⁵ This is a large number. It has been calibrated at a rate which would be required to increase the service share in consumption from the current level in China to a level consistent with the Australian share of services in household consumption.

⁶ This shift is calibrated such that, initially, the household sector's use of energy does not change, only the mix of that energy (i.e. towards gas and away from coal).

- Policy scenario four — a composite scenario

Policy scenario integrates all the assumptions in policy scenarios one, two and three.

4.2 Policy results analysis

4.2.1 Policy scenario one—an increase in the service sector

The effects on economic growth, income and energy intensity

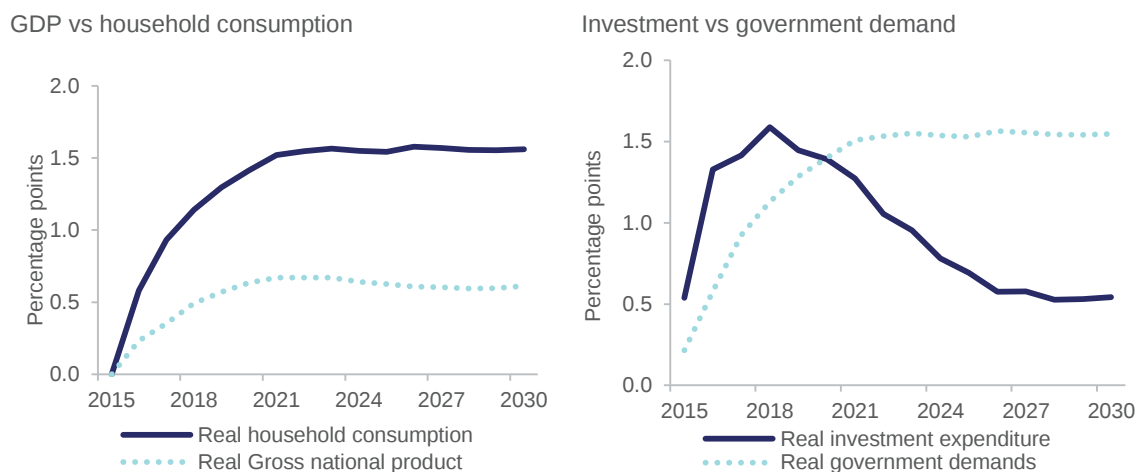
Policy scenario one posits an increasing share of the service sector in China's economy. This has immediate implications for overall economic growth, income and energy intensity.

In this scenario, economic growth is stimulated, meaning that both industry and households can afford, and are willing to pay for, cleaner fuel such as gas in industrial activities and for urban living. The modelling shows that, as total energy consumption increases, the share of gas consumption increases, which leads to higher gas demand, increased gas production and a faster growth in imports than in the baseline scenario.

Increasing the share of output generated from services benefits overall employment, because the service sector is expected to generate more jobs per unit of GDP than industry (Rutkowski 2015). This leads to rising aggregated income and increasing private consumption.

Figure 6 shows how this policy scenario results in real household consumption growing faster than real GDP relative to the baseline. Annual growth deviates by 1.6 percentage points for real household consumption, compared with 0.6 percentage points for real GDP. Figure 6 also shows that — despite faster growth in government demand and investment expenditure in this policy scenario relative to the baseline — the growth in investment expenditure starts to decline from 2019. At the same time, growth in government demand continues to rise until about 2023 (when it plateaus). By 2030, annual investment expenditure is 0.5 percentage points higher than for the baseline. Government demand is 1.5 percentage points higher.

Figure 6: Cumulative growth deviation for macroeconomic indicators in policy one from baseline, 2015–30



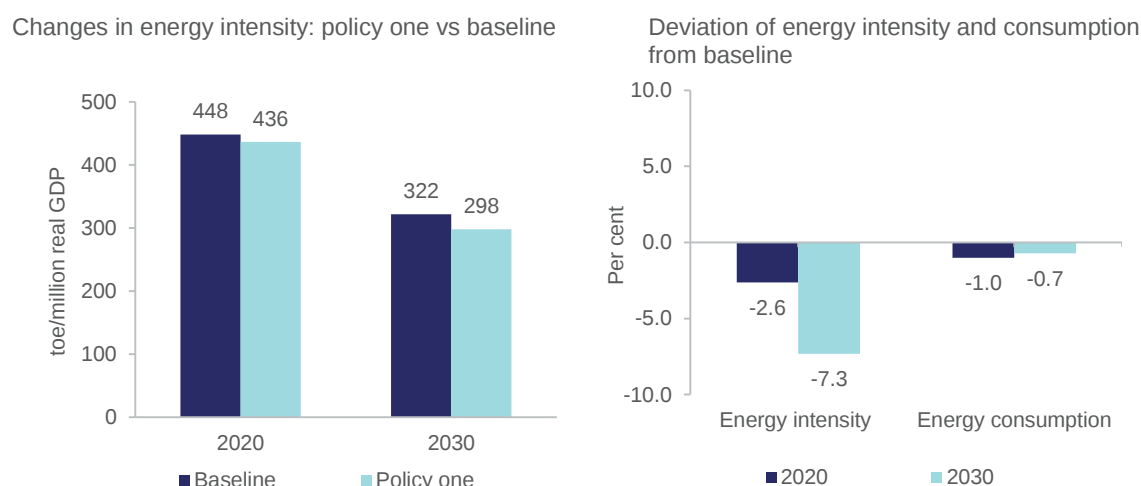
GDP = gross domestic product

Source: CHINAGEM

The service sector is less energy intensive than the secondary sector, which comprises manufacturing. The secondary sector in China relies much more on coal as a source of energy than the service sector.

This policy scenario aims for sustainable economic growth and a reduction in the relative share of energy consumption. This results in lower energy intensity. Figure 7 shows that energy intensity will be reduced from 528 toe per million dollars of GDP (in 2015) to 436 toe per million dollars in 2020 and 298 toe per million dollars in 2030. China's energy intensity reduces by 3 per cent in 2020 and 7 per cent in 2030 relative to the baseline. For example, with a reduction of total primary energy consumption, GDP growth in this policy scenario increases by 0.6 percentage points per year in 2020 and 0.4 percentage points per year in 2030, relative to the baseline.

Figure 7: Changes in energy intensity and deviation from baseline, 2020 vs 2030



Note: Energy intensity is measured by primary energy consumption in tonnes of oil equivalent (toe) per million dollars of gross domestic product (GDP) in 2005 prices.

Source: CHINAGEM

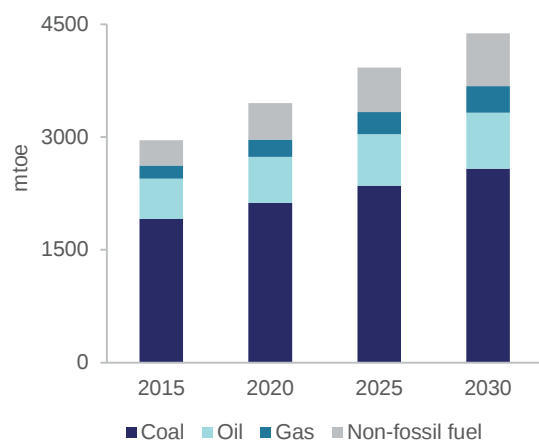
The effect on natural gas consumption

When the share of the service sector increases, the overall economy becomes richer and society shifts its focus towards consumption and away from savings. A further consequence is that households will switch from using low-grade coal for heating to gas. This gives a significant opportunity for future growth of gas demand, especially in the wealthy coastal regions (Li 2015). An increasing share of the service sector in the total economy stimulates total energy consumption and GDP growth relative to the baseline during the forecast period. Despite a reduction in energy intensity, the higher incomes seen as a result of scenario one mean that households will prefer cleaner fuels in the form of gas or non-fossil fuels for their urban living compared with the baseline scenario.

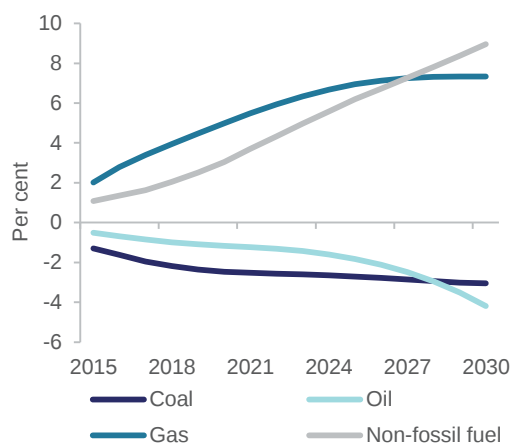
Figure 8 shows that total energy consumption is projected to increase from 2,956 mtoe in 2015 to 4,379 mtoe in 2030. During the next 15 years, the growth in consumption of natural gas and non-fossil fuels is faster than the consumption growth for coal and oil. The compound annual growth rate (CAGR) for the forecasted period of 2015–30 for both natural gas and non-fossil fuels is expected to be 5 per cent, compared with 2 per cent for the growth rate of coal and oil. This implies that, by 2030, there is a cumulative increase for non-fossil fuel and gas consumption of 9 per cent and 7 per cent, respectively, relative to baseline. This compares with cumulative declines of 3 per cent and 4 per cent for coal and oil consumption, respectively, by 2030 relative to baseline.

Figure 8: Primary energy consumption in policy one and cumulative changes by fuel type from baseline, 2015–30

Primary energy consumption by fuel type in policy one



Cumulative changes in fuel consumption relative to baseline

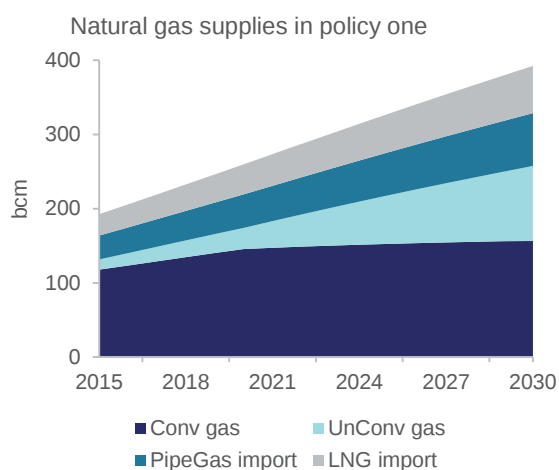


mtoe = million tonnes of oil equivalent

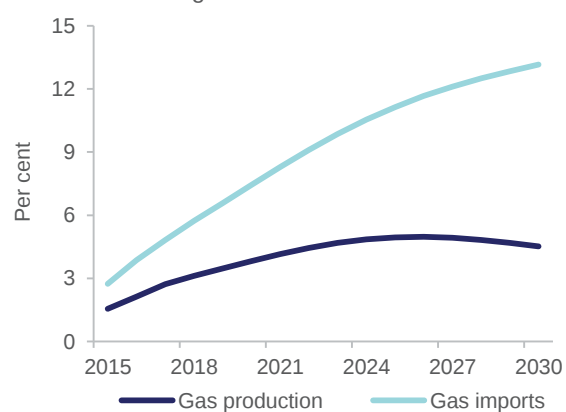
Source: CHINAGEM

To meet the increased demand for natural gas in this policy scenario, China's gas imports are growing faster than natural gas production relative to the baseline. Figure 9 shows that natural gas consumption is projected to double in the next 15 years to 392 billion cubic metres (bcm) in 2030. To meet this increased gas demand, natural gas imports and production will double to 135 bcm and 257, respectively, by 2030. From 2015 to 2030, unconventional gas production will increase seven-fold from a low base, and its share in total gas production will rise to 60 per cent in 2030 from 12 per cent in 2015. In the policy scenario alone, the cumulative gas imports grow by 13 per cent compared with the baseline by 2030, which is much faster than the cumulative growth of 5 per cent for indigenous gas production.

Figure 9: Natural gas demand, supply in policy one and cumulative changes from baseline, 2015–30



Cumulative changes from baseline



bcm = billion cubic metre; Conv = conventional; LNG = liquefied petroleum gas; PipeGas = pipeline gas; UnConv = unconventional gas

Source: CHINAGEM

4.2.2 Policy Scenario two -capping coal consumption by 2020

The second policy scenario involves a lower growth rate in coal consumption, with a cap on total coal consumption in place from 2020. This policy has a number of implications for economic growth and energy consumption in China. Firstly, the modelling shows that GDP growth is marginally lower than in the baseline scenario, as this scenario lacks any countervailing drivers of economic growth, such as a shift to a larger service sector. Secondly, total energy demand is also lower than the baseline, although there is growth in natural gas consumption of around 25 per cent by 2030 relative to baseline as a result of switching from coal to natural gas and alternative fuels.

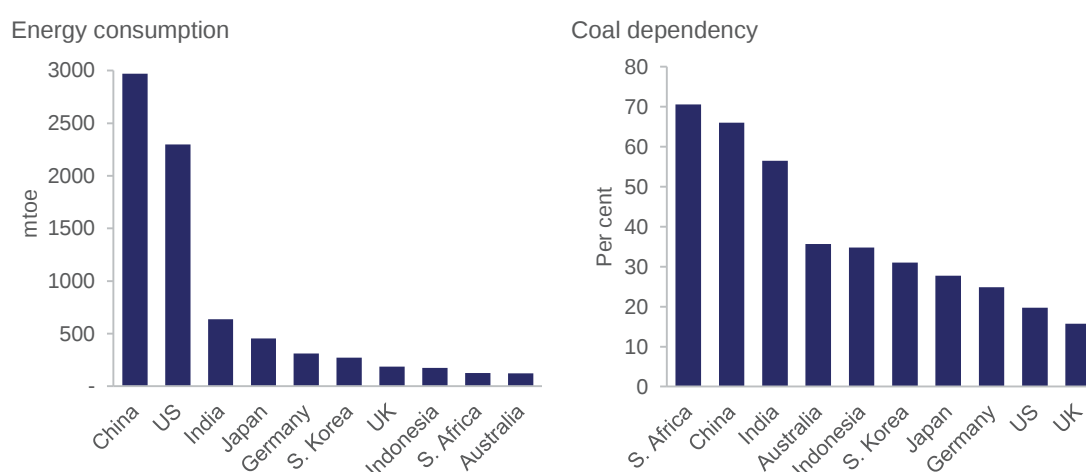
Of particular note is the shift in gas consumption among sectors. The results show an increase in consumption overall in all sectors, but the relative share of gas consumption shifts from the traditional industrial sectors to the emerging sectors. A further consequence of this policy is a significant reduction in CO₂ emissions and in the emission intensity of the economy.

The argument for reducing coal dependency

For a long time, coal has dominated China's energy supply and demand because of its abundance and low cost relative to other fuels. For example, in 2014, China consumed about 3 billion tonnes of oil equivalent (btoe) of coal, which comprised 66 per cent of China's total primary energy consumption. This was 10 percentage points higher than India, 38 percentage points higher than Japan and 46 percentage points higher than the United States (see Figure 10).

The high level of domestic coal dependency in China is partly a result of the imbalance in the endowment of fossil fuels in China, with coal being more prevalent compared with other fossil fuels. Concerns for self-sufficiency and energy security have led to high levels of coal usage and high rates of production from the domestic resource. Coal self-sufficiency, as measured by the ratio of domestic coal production to consumption, was 94 per cent in 2014. Although countries such as Indonesia and the United States are completely self-sufficient in coal supply and are net exporters, coal is a much smaller percentage of their total primary energy consumption because large volumes of other fossil fuel resources are available (Aden et al. 2009).

Figure 10: Comparative total primary energy consumption and coal dependency, selected countries, 2014



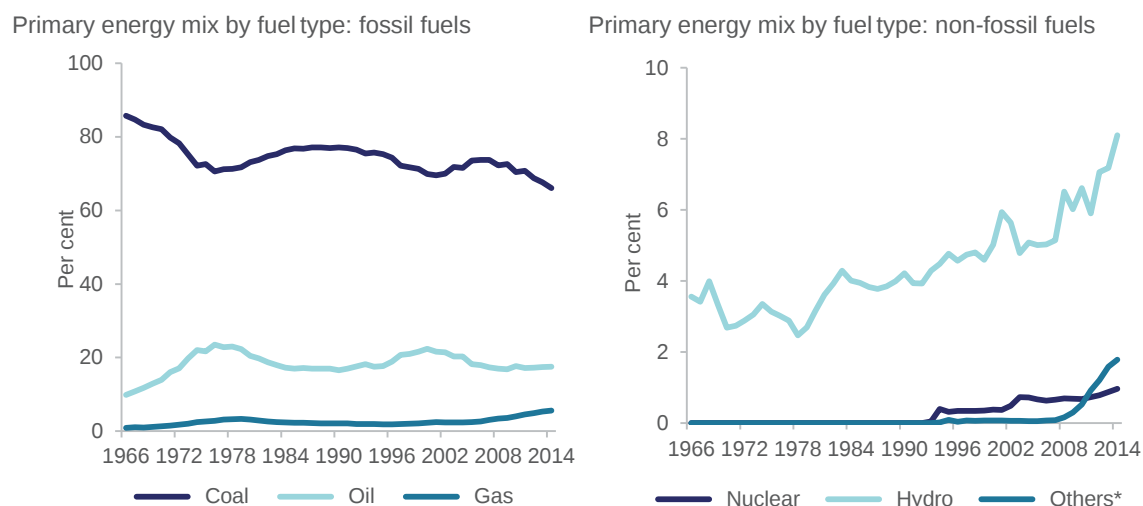
mtoe = million tonnes of oil equivalent; UK = United Kingdom; US = United States

Source: BP (2015) and authors' calculations

Despite the concern for self-sufficiency, coal's share in China's total energy consumption has fallen gradually from 87 per cent in the mid-1960s to 66 per cent in 2014, with an increasing share of natural gas and

renewables in the primary energy mix (particularly since 2000). However, although the share of natural gas consumption has recently increased, it is still a significantly lower share of primary energy consumption than coal (as shown in Figure 11), accounting for only 5.6 per cent of China's primary energy use in 2014. This is about four times below the global average rate (about 24 per cent). China has experienced very rapid growth in the usage of natural gas during the past decade. The use of renewable fuels has also grown, albeit from a very low base. From 2000 to 2014, gas consumption increased seven-fold, as did nuclear power generation. Hydroelectric power generation increased five-fold, whereas other renewables increased 74-fold (once again from a very low base).

Figure 11: Trend of primary energy mix by fuel type in China, 1966–2014



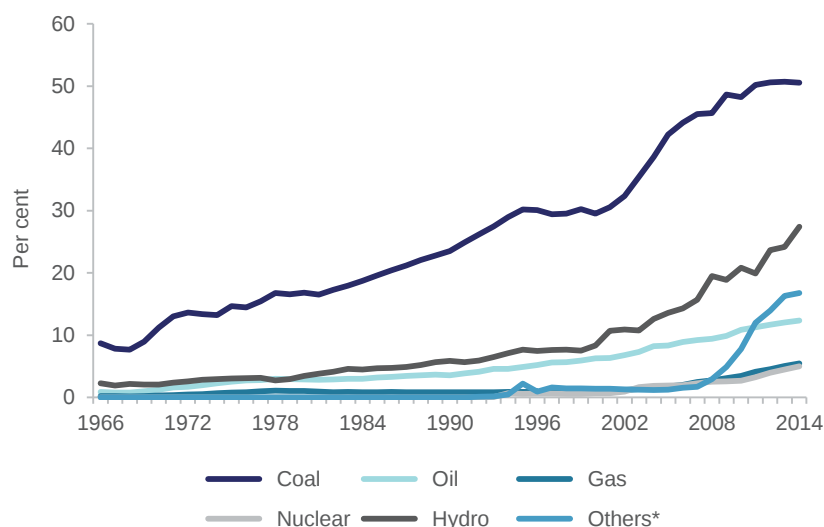
Note: Others includes solar, wind, geothermal and biofuels.

Source: BP (2015) and authors' calculations

Despite the relatively small shares of alternative fuels in China, the large size of the Chinese economy means that even small changes can have major implications for global demand and trade. Over the past decade, China has been the country with a fast economic growth that has led it to be the largest energy consumer and producer in the world. Rapidly increasing energy demand has made China influential in world energy markets (EIA 2015a).

China now produces and consumes almost as much coal as the rest of the world combined. In 2014, China accounted for about 50 per cent of global coal consumption. Figure 4.3 shows that natural gas and nuclear consumption accounted for 5 per cent of the world total, respectively, in 2014. China's oil consumption accounted for 12 per cent of the world total and renewable resources (including hydro) accounted for 44 per cent of the world total. China's role in driving global trends is changing as it enters a much less energy-intensive phase in its development.

Figure 12: Share trend of China's fuel consumption in the world's total, 1966–2014



Note: Others includes solar, wind, geothermal and biofuels.

Source: BP (2015) and authors' calculations

Although natural gas still comprises a relatively small share of China's total energy mix, it is becoming increasingly important because of a number of emerging policy priorities, including a greater emphasis on lowering air pollution and carbon emissions. Further exploitation of natural gas plays a substantial part in the government's response to growing air pollution issues, and the Action Plan builds upon the *12th five-year plan for natural gas development* (The State Council of the People's Republic of China 2014), including:

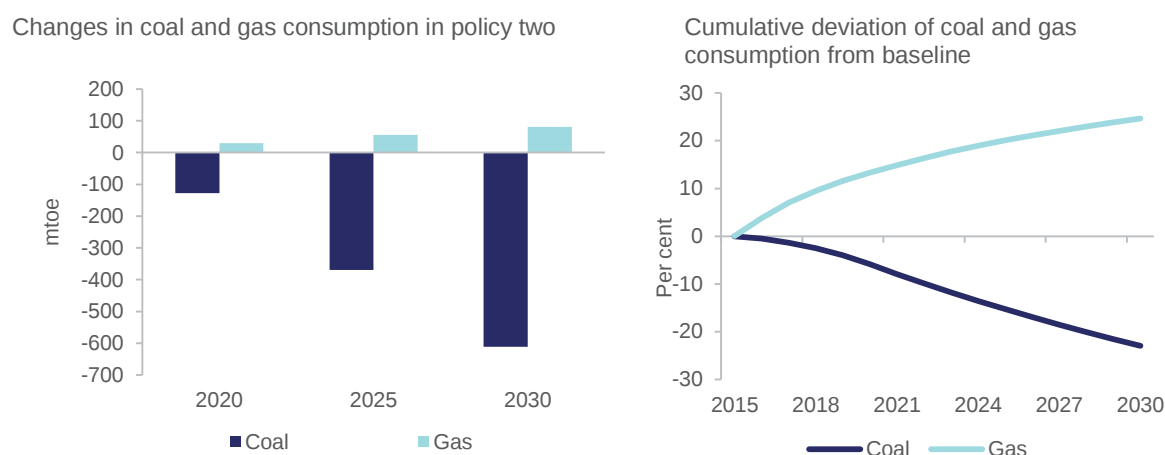
- accelerate the development of natural gas and renewable energy in order to realize a clean energy supply and diversified energy mix
- combine national natural gas pipeline networks, regional pipeline networks, LNG terminals, gas storages and other natural gas distribution projects to strengthen natural gas infrastructure construction in key regions.
- optimally allocate and use natural gas as well as develop a distributed natural gas system in accordance to the rules of the priority development of city gas, active adjustment of the industrial fuel structure, and modest development of natural gas power generation.

One of the key energy policy objectives in China is to reduce coal dependency in its primary energy and electricity generation mix. This will result in a shift to alternative fuels including natural gas, which can help to reduce CO₂ emissions and urban air pollution. In China, power generation and manufacturing are the largest consumers of coal and, thus, the largest CO₂ emitters. In particular, the steel industry, which is the pillar of manufacturing, has considerable potential for energy conservation and emissions reductions.

In the coal dependency policy scenario, the growth rate of primary coal consumption gradually decreases from 2015 and is zero after 2020. Total coal consumption peaks at 4.2 billion tonnes by 2020. This peak is assumed to be achieved by a demand-side policy intervention using the government's regulatory powers. Figure 12 shows that coal consumption in this policy scenario reduces by 128 mtoe in 2020 and by 611 mtoe in 2030 relative to the baseline. As a result, projected coal consumption is 23 per cent lower than in the baseline scenario in 2030, whereas projected gas consumption is 25 per cent higher. The simulation results also show that GDP growth is marginally lower relative to the baseline in 2030, because this scenario lacks any countervailing drivers of economic growth, such as a shift to a larger service sector.

This study does not explicitly examine how introducing a tax on coal and energy pricing will affect the coal share in the primary energy mix and CO₂ emissions. The revenues from a coal tax could partly be applied towards clean energy development, with a higher potential for fueling economic growth (Green and Stern 2015). China is set to introduce an emissions trading scheme in 2017 covering the power sector and heavy industry. This scheme will help to curb the appetite for coal, and lead to a flattening and then a peak in China's CO₂ emissions around 2030 (IEA 2015c). Nevertheless, taxes and price will influence investment decisions on coal and other alternative fuels.

Figure 12: Changes in coal and gas consumption in policy two and deviation from baseline, 2015–30



Mtoe = million tonnes of oil equivalent

Source: CHINAGEM

The implication for emission intensity

China's rapid economic development has driven ever-increasing energy use (especially electricity generation). In 2014, coal accounted for 72 per cent of the electricity generation mix, although it has declined from 81 per cent in 2007. Despite this decline, the electricity output generated by coal increased from 2.7 trillion kWh in 2007 to 4 trillion kWh in 2014. Electricity generation accounted for more than 50 per cent of China's total CO₂ emissions from fuel combustion. The Chinese government has shut down less-efficient small- and mid-sized coal plants, replacing them with large, high-efficiency units (IEA 2015a).

Since 2013, China has been pursuing the targets for addressing climate change set out in its 12th Five-Year Plan — implementing the action plan for controlling greenhouse gas emissions, adjusting the country's industrial structure and increasing energy efficiency. Policies for energy efficiency include upgrading low-carbon technology, undertaking innovation and attempting to resolve overcapacity. In October 2013, the General Office of the State Council issued the *Opinion on further strengthening coal mine safety*, proposing to close more than 2,000 small coal mines nationwide by the end of 2015 (NDRC 2014b). China is implementing an action plan, released by the National Energy Administration in 2015, for the clean and efficient use of coal between 2015 and 2020. The plan includes increasing coal quality and controlling residential coal use. To improve coal quality, China will invest in large-scale coal-washing capacity to ensure that 70 per cent of raw coal is washed by 2017 and more than 80 per cent by 2020 (from around 40 per cent in 2015).⁷

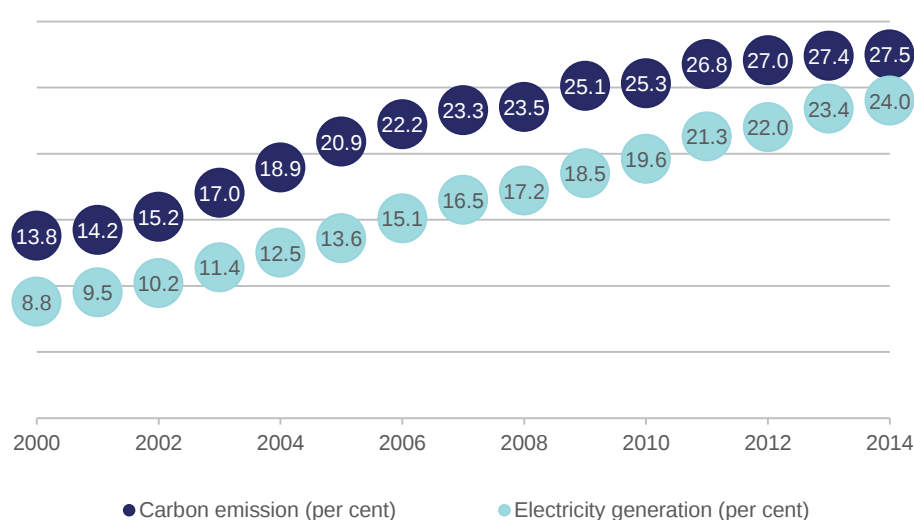
However, China's endowment of relatively cheap domestic coal resources makes it difficult to significantly reduce coal use for generating power (IEA 2012). Higher gas prices in China make coal-to-gas switching far less

⁷ <http://en.sxcoal.com/117736/DataShow.html>

attractive in comparison with constructing high-efficiency coal-fired plants (the most widely available and deployed technology) (IEA 2015a). China has taken steps to develop and construct highly efficient coal-fired power plants, and retire some of its most inefficient coal-fired power plants (IEA 2015a).

Carbon emissions have risen alongside electricity generation. China's electricity use accounted for 24 per cent of global electricity generation in 2014, a three-fold increase since 2000. In comparison, China contributed to 28 per cent of the global CO₂ emissions (see Figure 13) in 2014. The scale and age of China's existing coal-fired power generation capacity highlights the risk of high carbon lock-in in its energy supply infrastructure. Much of China's coal-fired power capacity has been constructed since 2000, meaning that it is technically capable of continuing to operate for decades to come (IEA 2015a), and must do so to yield the expected returns on investment. In addition to high CO₂ emissions from power generation, large increases in the production of energy-intensive materials, such as cement and steel, have also driven China's CO₂ emissions.

Figure 13: Shares of China's electricity and emissions in the world, 2000–14



Source: BP (2015) and authors' calculations

Setting 2020 as the year for China's coal consumption to peak is one of the policies designed to reduce CO₂ emissions and air pollution. Although a **national cap on coal consumption builds on other efforts to protect the environment**, it also conserves resources and provides a basis for future growth in clean energy industries. In the absence of other policies, peaking coal consumption by 2020 results in a reduction in both total energy consumption and GDP growth relative to the baseline.

A policy of peaking coal consumption in 2020 will reduce total carbon emissions from coal. However, carbon emissions from natural gas will increase as more natural gas is used. In this policy scenario, by 2030:

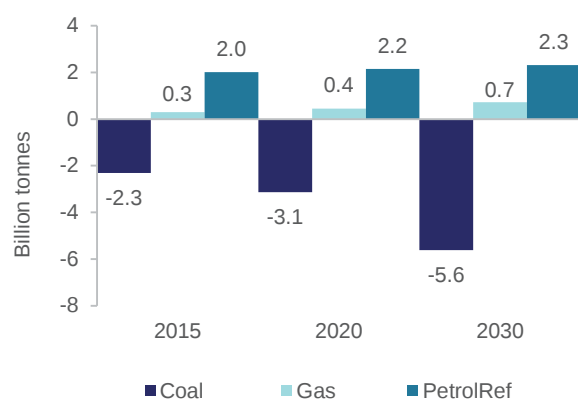
- total carbon emissions decline to 11 billion tonnes from the baseline 13.6 billion tonnes
- the projected decline of carbon emissions from coal consumption is more than two-fold, but the carbon emissions from natural gas doubles relative to the baseline
- total emissions intensity declines by 61 per cent (from 2007) compared with a deduction of 57 per cent in the baseline.

Figure 14 shows that, by 2030, coal-based carbon emissions are 5.6 billion tonnes lower than the baseline, and natural gas-based carbon emissions are 0.7 billion tonnes higher than the baseline. Gas consumption is higher — not only in power generation, but also in industrial uses and urban living. The small increase in CO₂ emissions from petrol refineries reflects a strong substitution between coal, and gas and renewables, and an

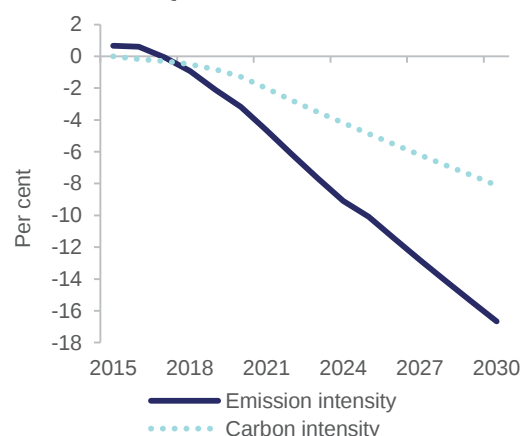
upsurge in the small amount of oil used for primary energy consumption. As a result, emissions intensity is 17 per cent lower and carbon intensity (defined as the ratio of carbon emissions to total energy consumption) is 8 per cent lower than the baseline by 2030.

Figure 10: Changes in carbon emissions and carbon intensity in policy two from baseline, 2015–30

Changes in carbon emissions, selected years



Cumulative deviation of emission intensity and carbon intensity from baseline



Note: PetrolRef is processing of petroleum.

Source: CHINAGEM

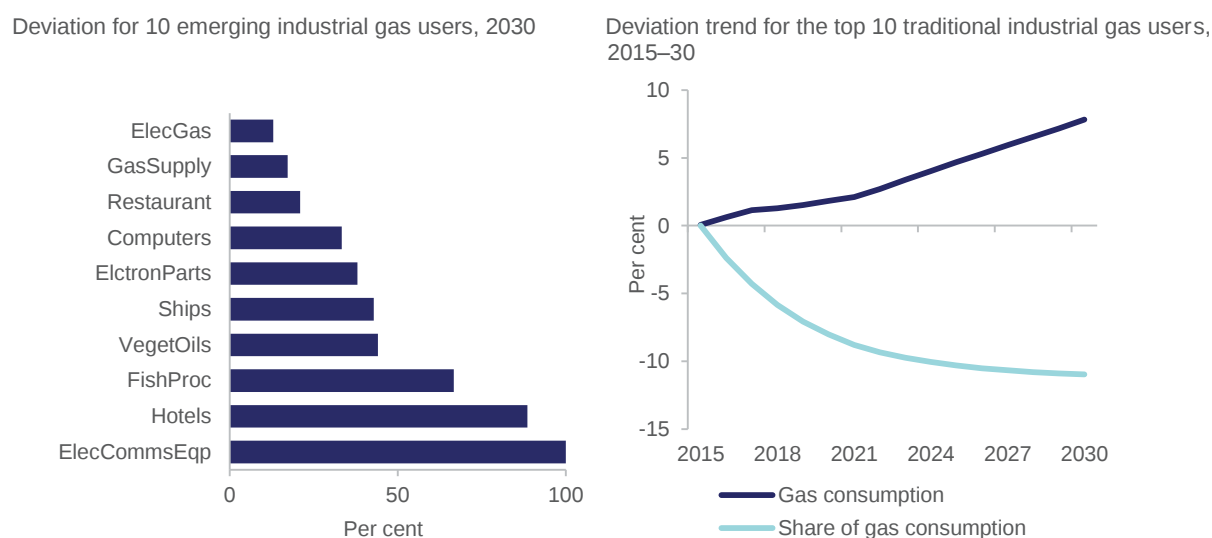
The impact on industrial users of natural gas

Achieving a national coal cap would depend predominantly on the industrial sector. Key coal-consuming industries include power, iron and steel, cement, and building. In the industrial sector, natural gas typically competes against coal, oil products and electricity. Natural gas is also used by industry for non-energy purposes, mainly as a feedstock for the manufacture of fertilisers and petrochemical products.

The gas supply industry provides gas services to the residential and transportation sectors. In policy scenario two, the gas used in non-energy sectors as an intermediate input increases for non-traditional industrial gas users (relative to the baseline), and replaces petroleum products. This is coupled with a reduction in the use of gas in some energy-intensive sectors, such as steel and coking production. Replacing petroleum products with gas products reflects that, in the transport sector, use of natural gas vehicles can significantly improve air quality, because natural gas vehicles have lower NO_x and SO_x emissions. Using natural gas for transport could reduce petrol and diesel consumption, which is a key driver of China's oil products demand.

Zero growth in primary coal consumption after 2020 has a major impact on natural gas consumption for industrial users. Figure 15 shows the 10 industries with increased deviations in the range of 10–100 per cent for natural gas consumption relative to the baseline in 2030. These industries are grouped as gas use for energy production, or for feedstock in agriculture, manufacturing and services. Most are non-traditional or emerging industrial gas sectors, such as hotels, restaurants and computers, and manufacturing that is less energy intensive. Figure 4.7 also shows the cumulative change in gas consumption for the 10 largest traditional industrial gas users. Gas consumption is 9 per cent higher than the baseline, but the share of gas consumption is 11 per cent lower by 2030. The top 10 traditional industrial gas users account for 71 per cent of total industrial gas consumption each year under this policy scenario, which represents a decline from 79 per cent compared with the baseline.

Figure 15: Cumulative deviation from baseline of primary gas used by industries in policy two



Note: ElecGas refers the sector of electricity generated by gas. Restaurant is the sector of catering services. Computers refers the sector of Manufacture of Computers. ElctronParts refers the sector of Manufacture of Electronic Component. Ships refers the sector of Manufacture of Boats and Ships and Floating Devices. VegetOils refers the sector of Refining of Vegetable Oil. FishProc refers the sector of Processing of Aquatic Product. ElecCommsEqp refers the sector of Manufacture of Communication Equipment.

Source: CHINAGEM

4.2.3 Higher unconventional gas production

The third policy scenario involves an increase in unconventional gas production. This will have implications for both the level of total gas supply and the quantity of natural gas imports into China. Given the current state of technology in the production of unconventional gas in China, there is significant scope for productivity gains over time. Any productivity improvement lowers the unit cost of production and increases the competitiveness of unconventional gas in the national gas market. As the competitiveness of unconventional gas improves, so does its share in the national market. Hence, in the third policy scenario, there is an increase in unconventional gas production relative to conventional gas production and imported supply.

One result of accelerating unconventional gas production is a reduction in supply from conventional gas sources relative to the baseline. Nevertheless, total indigenous gas production is higher in this scenario, as gas demand is stimulated by the reduction in gas production costs. However, demand does not grow as fast as production and, hence, there will be a decline in natural gas imports. This means that, in this scenario, the import dependency of natural gas will decline relative to the baseline.

The prospects for unconventional gas

In 2014, China was the world's third largest gas consumer, trailing only the United States and Russia. This represents rapid growth in demand since 2000, when China ranked 21st in the world. Domestic production also surged during this time. China ranked sixth in the world in total gas production in 2014, increasing its production five-fold between 2000 and 2014. Its share of proven reserves is small, however, with less than 2 per cent of the world reserves, ranking 13th after Australia and Iraq.

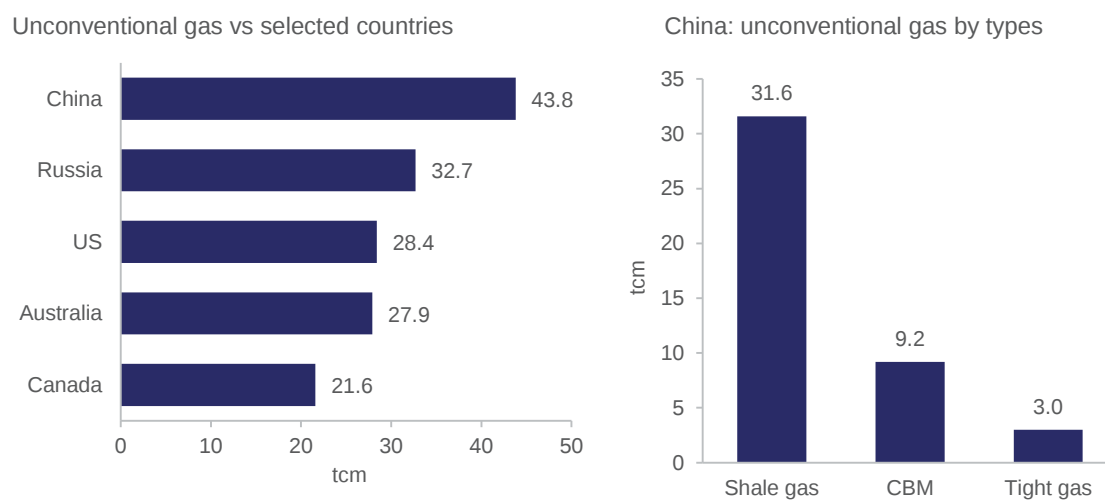
China's indigenous gas production is dominated by conventional gas, accounting for more than 90 per cent of its total natural gas production in 2014. However, its unconventional gas production has huge potential. Unconventional gas refers to gas produced from coal seams (coal seam gas or coalbed methane), shale (shale gas) rocks, and rocks with low permeability (tight gas). Once gas is produced from these reservoirs, it has the

same properties of gas produced from ‘conventional’ (i.e. sedimentary reservoirs with high porosity and permeability) sources.

Like many other countries, such as the United States and Russia, China has rich unconventional gas resources estimated to be 44 trillion cubic metres (tcm). These reserves are dominated by shale gas (more than 30 tcm), which accounts for almost three-quarters of the total, and coalbed methane, which accounts for 9.2 tcm in 2015 (Figure 16).

China is currently the largest shale gas producer outside North America, but it faces significant challenges in developing its shale resources. The shale is deeper (up to 6,000 meters below ground) and tends to have more clay than United States shale. In addition, scarce water reserves in the Ordos and Tarim basins (IEA 2014a) — where many shale gas beds lie — make the cost of extraction higher in China. Although China’s national firms are partnering with selected international firms, it is likely to take considerable time to develop effective technological solutions and commercial arrangements to produce and supply large-scale shale gas to the Chinese market (Sheehan et al. 2014).

Figure 16: Remaining technical recoverable unconventional gas resources in China, 2015



CMB = coalbed methane; US = United States

Source: IEA (2015c)

China's primary onshore natural gas-producing regions are:

- Sichuan province in the southwest (Sichuan Basin)
- the Xinjiang and Qinghai provinces in the northwest (Tarim, Junggar and Qaidam basins)
- Shanxi province in the north (Ordos Basin).

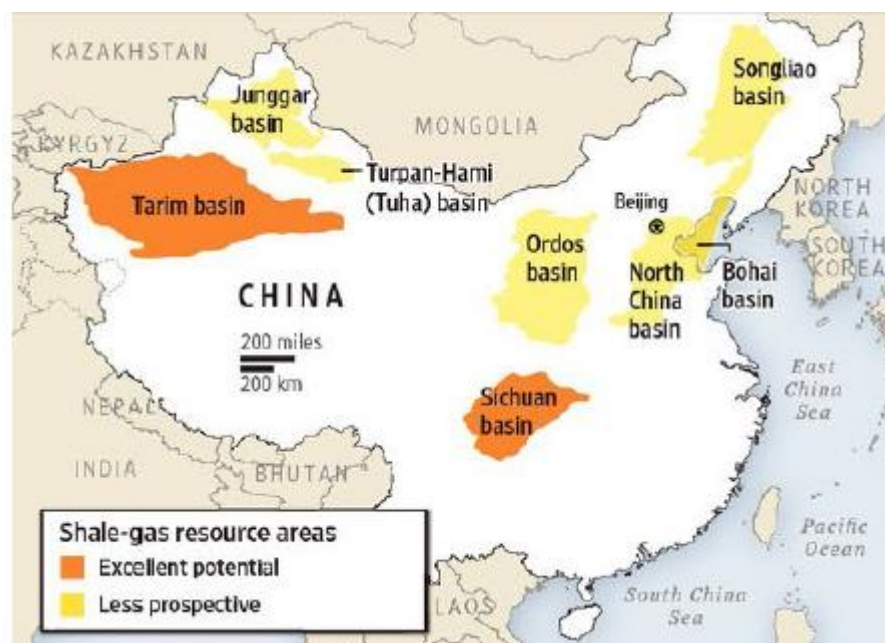
China has delved into several offshore natural gas fields located in the Bohai Basin and the Panyu complex of the Pearl River Mouth Basin (South China Sea), and is also exploring more technically challenging areas (including deep water, coalbed methane and shale gas reserves) with foreign firms.

Most of China’s shale gas reserves are located in Sichuan and Xinjiang (Tarim Basin) (see Figure 17). Sichuan is densely populated and has a high level of agricultural activity with a high demand for water. It also has unstable geological conditions. Extraction and transportation costs are therefore high. Tarim Basin is located close to the Kazakhstan border and far away from the main consumption centres of natural gas in China which will require costly investment in long-distance pipelines (Dehnavi and Yegorov 2014).

As Chinese firms have gained experience producing from shale, the cost of shale gas drilling has declined. By mid-2015, the cost of drilling a horizontal well in shale formations in the Sichuan Basin was between US\$11.3 million and US\$12.9 million per well, according to the China's National Petroleum Corporation's Economics and Technology Research Institute (Jin 2015). Sinopec, one of China's national oil firms, reports that this range was 23 per cent lower than in 2013 (Jin 2015). However, the cost of drilling one shale gas well in China is still more than double the drilling cost in the United States (Dehnavi and Yegorov 2014), which is about US\$4 million per well and up to around US\$7 million for more complex wells (IEA 2015c). There are several reasons for the higher costs of production in China, including limited economies of scale and complex geologies. For example, in southern China shale gas production is in the mountainous terrain, and water shortages pose problems in western China. Water scarcity in particular (e.g. high groundwater stress and seasonal variability) may make the cost of drilling prohibitive in the Tarim Basin in Xinjiang province, where China's second-largest shale gas play is located (Wang 2015).

Declining well costs and increasing experience in developing shale gas reserves, supplemented by government investment incentives, have promoted further investment in the development of shale gas resources. In 2012, to encourage the exploration for shale gas, the Chinese government established a four-year, \$1.80 per million British Thermal Units (mmBtu) subsidy programme for any Chinese firm achieving commercial production of shale gas. In mid-2015, this subsidy was extended to 2020, but at a lower rate (EIA 2015b). Enhanced financial incentives for investment are provided as part of the designation of shale gas as one of the nation's strategic emerging industries. However, uncertainties regarding future liberalisation of prices and third-party access, along with the absence of detailed rules to regulate shale gas activity, are among a number of factors holding back further growth. Shale gas will not become a major energy source for China in the short term because of a range of technical, institutional and infrastructure constraints (Liu 2014). In the long term, shale gas is expected to make a major contribution to China's natural gas supplies, and provide the benefits of lower costs, energy security and environmental protection.

Figure 17: Map of China's shale oil and gas basins



Source: Wayne (2012)

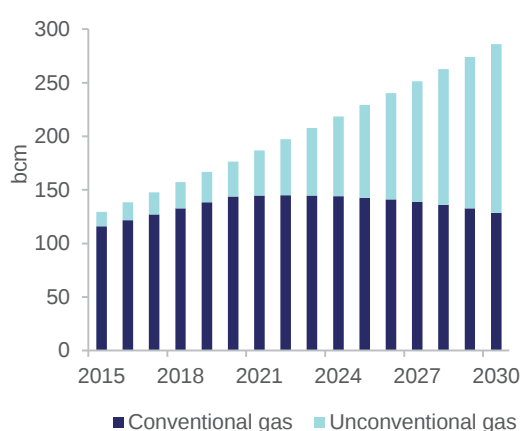
The increase in indigenous unconventional gas production leads to technological improvements and applications, and increases the scale of economies involved in drilling and infrastructure. The increase in production comes partly at the expense of reduced production from conventional sources. This change in the

relative quantity produced is in response to a change in the relative price of output. The change in relative price lowers the price of unconventional gas relative to conventional gas through productivity improvements, which reduces the average cost of production of unconventional shale oil gas.

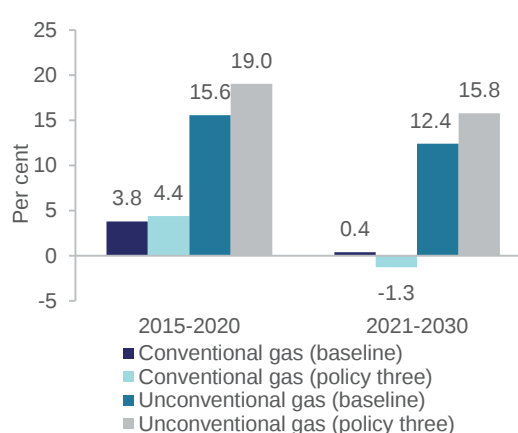
Figure 18 shows how unconventional gas production rises and conventional gas production declines post-2020. The production of unconventional gas overtakes that of conventional gas in 2030, accounting for 55 per cent of total gas production, compared with the current share of 10 per cent. This is 15 percentage points higher than the baseline share by 2030. Figure 5.2 also shows that conventional gas production grows in the short-run to 2020, but declines relative to baseline in the long-run to 2030. In all scenarios, unconventional gas production grows faster than conventional gas production.

Figure 18: Changes in indigenous gas production: conventional vs unconventional, 2015–30

Gas production in policy three



Gas production growth: policy three vs baseline



bcm = billion cubic metre

Source: CHINAGEM

The implications for natural gas imports

Unlike other countries in the Asia–Pacific region, such as Japan and South Korea, that are almost entirely dependent on LNG for their gas supplies, China has multiple sources of supply. It can source gas from its own indigenous resources, or import natural gas as LNG or through pipelines. Geographically, China is well positioned to access foreign natural gas supplies both by means of marine transport from the Asia-Pacific and the Middle East region and by pipeline transport from gas-rich regions such as Central Asia and Russia.

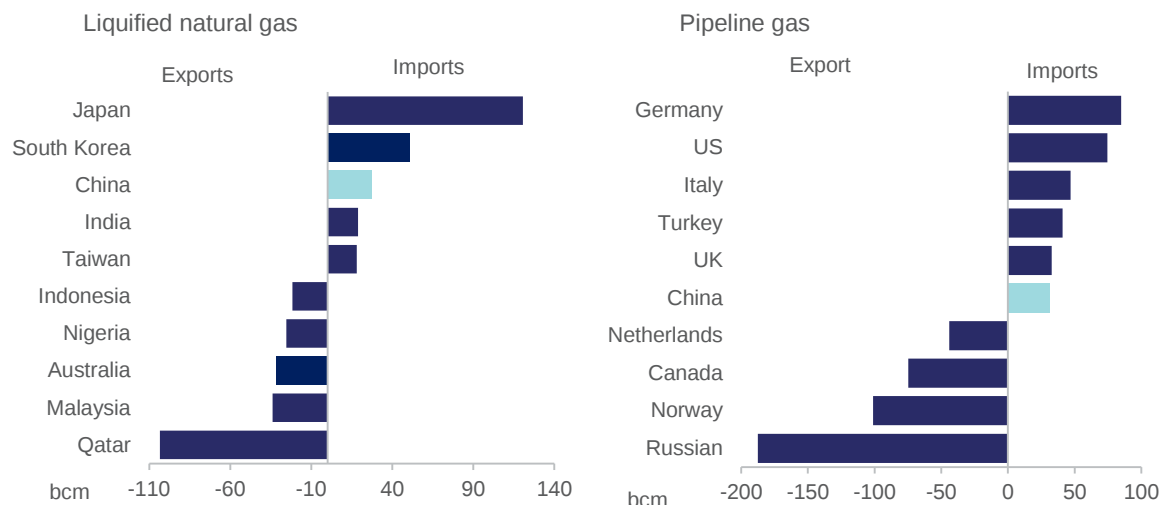
The costs of pipelining natural gas benefit substantially from economies of scale, since large diameter pipelines carry significantly more gas than smaller diameter pipelines but at a proportionate lower cost. Pipeline costs rise linearly with distance, but, LNG — which requires liquefaction and regasification regardless of the distance travelled — has a high threshold cost, but a much lower increase in cost with distance. Thus, shorter distance transport tends to favor pipelining of natural gas, but longer distances favor LNG.

China's strong growth in demand for natural gas has outpaced increases in domestic production, leading to greater imports sourced through both pipeline gas and LNG. In 2014, China was the world's third largest LNG importer and the world's sixth largest importer of pipeline gas (see Figure 19).

Pipeline gas is imported from Central Asia (such as Turkmenistan, Uzbekistan and Kazakhstan) in the west, from Myanmar (from offshore fields in the Andaman Sea) in the south, and from Russia in the north and north-west. On 21 May 2014, the decade-long negotiation with Russia on gas supply reached an agreement. Gazprom will provide 38 bcm/year from eastern Siberia to China's Bohai Bay region for 30 years, expected to

start in early 2020. Six months later, a memorandum of understanding was signed between Beijing and Moscow to deliver a further 30 bcm of gas for 30 years from the western route, which is also known as the Altai pass. LNG is delivered to China's eastern seaboard, mainly from the Middle East and Asia-Pacific regions, including Australia.

Figure 19: International exports and imports of natural gas: top 10 exporters and importers, liquefied natural gas vs pipeline gas in 2014



bcm = billion cubic metre; UK = United Kingdom; US = United States

Source: BP (2015) and authors' calculations

Growth in regasification capacity is an indicator of potential changes in LNG demand. China's regasification terminals are built on three coasts near major seaports:

- south coast imports go to Guangdong, Shandong, Hainan and Guangxi provinces, and Zhejiang and Shenzhen cities
- east coast imports go to Shanghai, Fujian, Jiangsu and Liaoning provinces, and Lianyungang city
- north coast imports go to Hebei province and Tianjin city.

Although China's south coast started its first LNG import in 2006, the regasification capacity in the area accounts for more than 42 per cent of China's total existing regasification capacity, compared with 39 per cent in the east coast and 18 per cent in the north coast. This trend is expected to continue with the majority of new regasification capacity being constructed and planned in the south coast (see Table 7). This reflects that the south coast is closer to the LNG-exporting countries such as Australia. In the north, LNG imports have stronger competition from pipeline gas. Table 7 also shows that, by 2020, the total regasification capacity is likely to be three times the current level.

Table 7: LNG regasification capacity (bcm), existing, under-construction and planned/proposed

<i>Location</i>	<i>Total capacity</i>	<i>Existing</i>	<i>Construction</i>	<i>Planned or proposed*</i>
South coast	57.12	18.08	15.08	23.96
East coast	44.62	16.80	11.46	16.36
North coast	24.2	7.82	4.14	12.24
Total	125.94	42.70	30.68	52.56

* Planned and proposed regasification capacities that are assumed to start their operations by 2020.

Source: Nexant (2015) WGM and authors' calculations

Based on the IEA's study in 2015 (IEA 2015b), the increase in LNG imports will be led by China and the non-Organisation for Economic Co-operation and Development countries in Asia and Europe. These countries account for more than 90 per cent of incremental additions. On the supply side, new LNG supplies will come primarily from Australia and the United States, which will account for 90 per cent of additional LNG exports between 2014 and 2020.

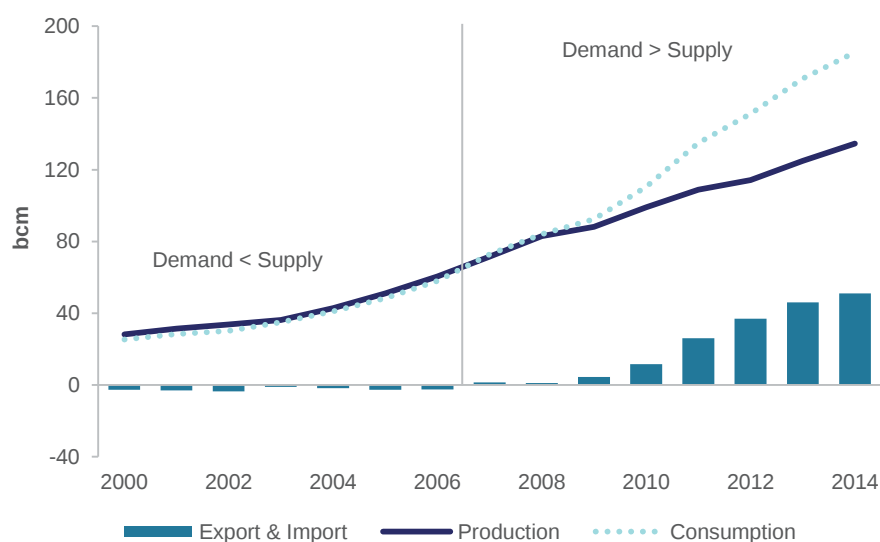
Relatively slow growth in China's gas production and rapidly increasing gas consumption has led to increasing gas imports during the past years. China began importing LNG in 2006. Imports of pipeline natural gas from Central Asia began in 2010, followed by imports from Myanmar in 2013. In 2014, China's natural gas imports were more than 50 bcm. In 2007, imported LNG was around 4 bcm, and increased seven-fold from 2007 to 2014 to more than 27 bcm. Imports of pipeline gas in 2010 were less than 4 bcm, but increased eight-fold to more than 31 bcm during the period of 2010 to 2014. In 2014, pipeline gas imports accounted for 53 per cent of total imports of natural gas compared with 22 per cent in 2010. Import dependency has increased from 2 per cent in 2007 to around 30 per cent in 2014.

From 2000 to 2014, China's gas consumption showed a seven-fold increase with a compound annual growth rate (CAGR) of more than 15 per cent (Figure 20). During the same period, China's gas production increased five-fold, with a CAGR of around 12 per cent.

The modelling results show that a policy to accelerate production of unconventional gas will lead to greater overall gas production and greater gas demand. However, the rate of growth of gas demand will trail the growth in production. This means that gas imports will grow marginally slower than in the baseline scenario.

Both indigenous gas production and gas imports will grow steadily in the next 15 years, but import growth is lower. Figure 21 shows that total gas production in scenario three will reach 286 bcm in 2030 compared with 246 bcm in the baseline, and that total gas imports will decline to 105 bcm from 119 bcm. The gas imports under this policy is 12 per cent lower and gas production is 16 per cent higher than in the baseline scenario by 2030.

Figure 20: Natural gas balance, 2000–14



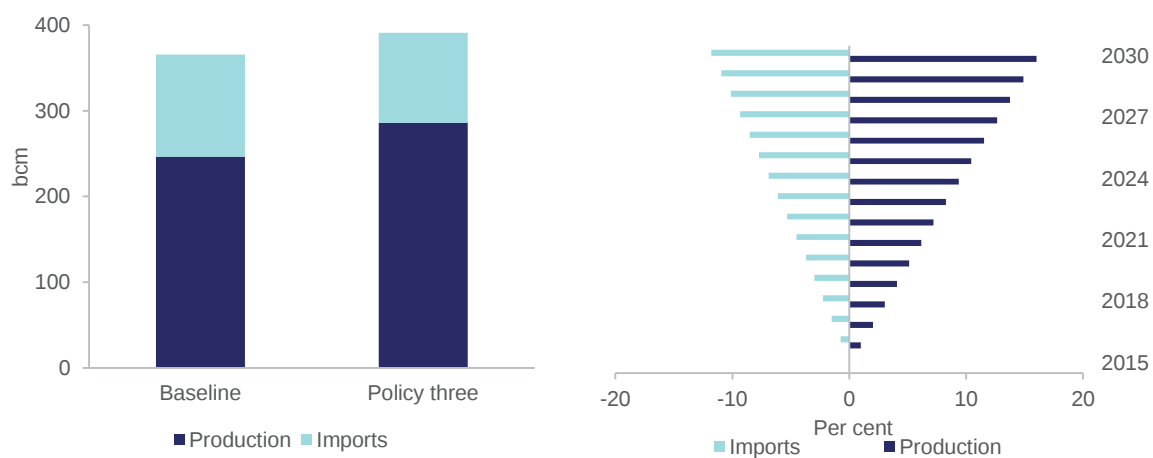
bcm = billion cubic metre

Source: BP (2015) and authors' calculations

Figure 21: Changes from baseline in gas imports and production in policy three

Gas imports and production in policy three vs baseline in 2030

Cumulative deviation in policy three from baseline, 2015–30



bcm = billion cubic metre

Source: CHINAGEM

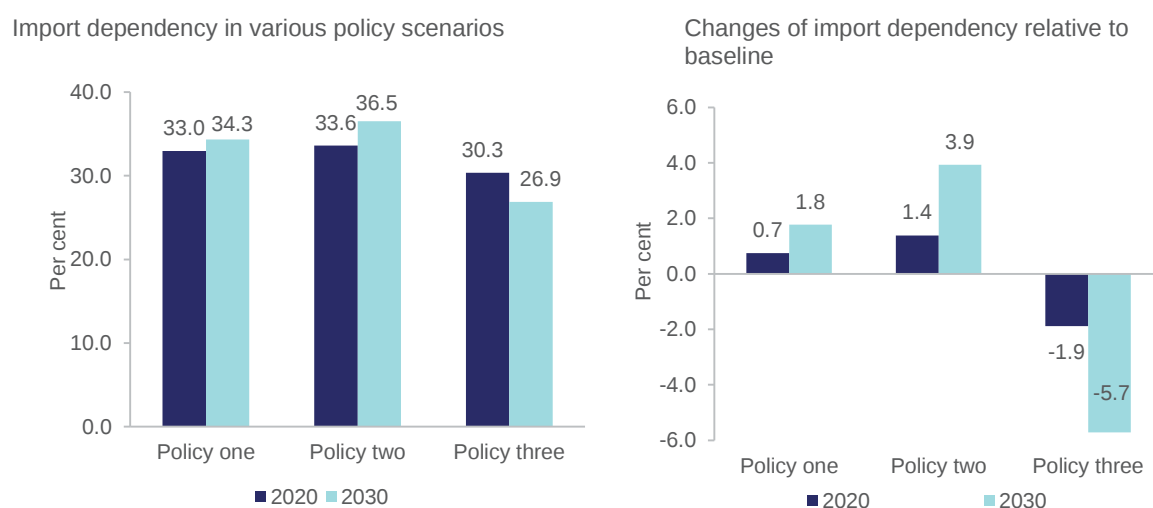
The effect on import dependency of natural gas

Import dependency is the percentage of gas imports to total gas consumption, and it is relevant to the policy goal of energy security. China's dependency on natural gas will continue to increase as it shifts away from coal as an energy source. This drives the increase in total gas imports and import dependency exhibited in the first two policy scenarios. However, in the unconventional gas policy scenario, increasing unconventional gas production has a negative effect on the total gas imports and import dependency.

Although this policy scenario implies lower conventional gas production relative to the baseline, total indigenous gas production rises as unconventional gas production grows at a faster rate post-2020. The declining rate of growth in gas consumption results in a decline in the growth rate of total gas imports.

Figure 22 compares the impact of each of the three policy scenarios on gas import dependency between 2020 and 2030. The baseline import dependency is 32.2 per cent in 2020 and 32.6 per cent in 2030. The import dependency in the unconventional gas policy (scenario three) decreases from 30 per cent in 2020 to 27 per cent in 2030. This results in import dependency declining by 2 percentage points in 2020 and 6 percentage points in 2030, respectively, relative to the baseline. The import dependency in the coal capping policy (scenario two) and the increase in the service sector policy (scenario one) are 4 percentage points and 2 percentage points higher than in the baseline, respectively, by 2030. Therefore, compared with the other two policies, increasing unconventional gas production strongly reduces gas import dependency. This policy results in a 10 percentage point reduction in import dependency compared with a policy of capping coal (37 per cent) and 7 percentage points lower than a policy to increase the service sector (34 per cent) by 2030.

Figure 22: Changes in import dependency of natural gas in various policy scenarios, 2020 vs 2030



Source: CHINAGEM

4.2.4 A composite policy and oil prices

In this section, the three policy scenarios are analysed jointly to determine the overall impact of multiple policy interventions in China's economy. In addition this analysis is supplemented by an examination of the impact of a range of future oil price scenarios on the level of gas imports and on the incentives for greater indigenous gas production in China.

Relative to the three individual policy scenarios, the composite policy scenario attains an effective balance between economic growth, environmental benefits and energy security arising from a more diversified energy supply. Modelling of the composite policy results in a higher share of natural gas in the primary energy and electricity generation mixes, higher LNG imports, improved air quality from the lower coal consumption, and lower carbon emissions from the shift away from coal to gas.

The analysis of oil prices, in conjunction with the composite policy, shows that higher oil prices linked to LNG prices will lead to lower LNG imports, but will provide higher returns to capital investment and incentivise indigenous gas production.

A composite policy and its effects

China is likely to reform all three policies during the forecast period. Therefore, not only do we need to gain insight on the key factors associated with each policy in isolation, but it is also important to consider the interaction of the three policies in combination.

China's natural gas imports are expected to expand to meet the continually increasing gas demand from the power, industrial, residential and transport sectors. Unconventional gas production increases, but the volume of production over time is uncertain. Despite the effects of oil price volatility, gas supply availability and capital intensive infrastructure, it is pricing reform, and government policy and funding to promote natural gas over other fuels that are the key factors affecting the speed at which the switch to gas and LNG occurs.

In this section, the discussion focuses on the main comparative effects from the composite policy relative to each of the three distinct economic and energy policies presented previously.

- Scenario one — an increase in the service sector

Compared with scenario one, the composite policy results in higher economic growth, higher income and lower total primary energy consumption. China has less of a need to produce fossil fuels from resources in the economy and energy intensity is lower. Higher gas demand is met by both higher indigenous gas production and gas imports.

- Scenario two — capping coal consumption by 2020

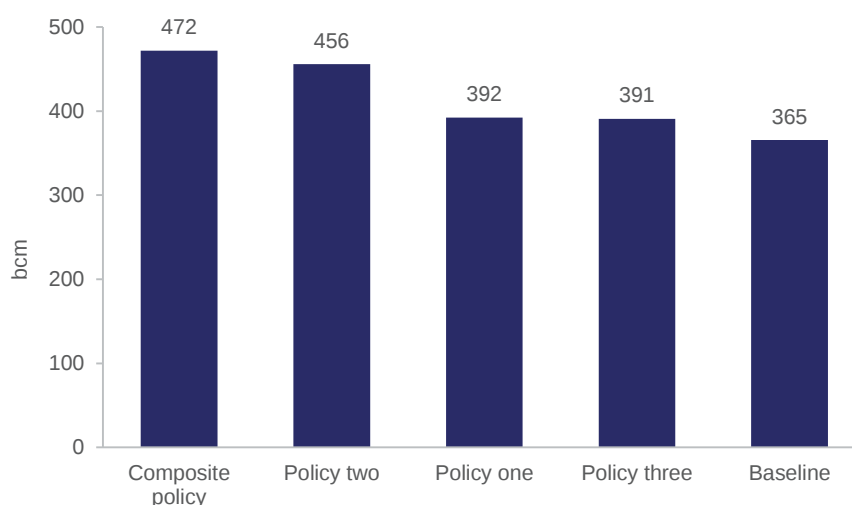
Compared with the scenario two, the composite policy shows continued reduction in carbon emissions combined with higher economic growth and higher total energy consumption. Emissions intensity is lower and gas imports are higher, but there is only a small reduction in indigenous gas production.

- Scenario three — higher unconventional gas production

Compared with the scenario three, the composite policy results in lower total energy consumption and higher gas demand. The accelerated increase in unconventional gas production crowds out small production of conventional gas. There is less total indigenous gas production and more gas imports, leading to higher gas import dependency (12 percentage points higher).

The impact of all four policy scenarios on total natural gas consumption is shown in Figure 23. It is clear that the composite policy leads to significantly higher gas consumption (29 per cent) than the baseline scenario. This is only marginally greater than the results for scenario two alone (coal consumption capped), but significantly higher than the results for the other two scenarios.

Figure 23: Comparative total gas consumption in various policy scenarios in 2030



bcm = billion cubic metre

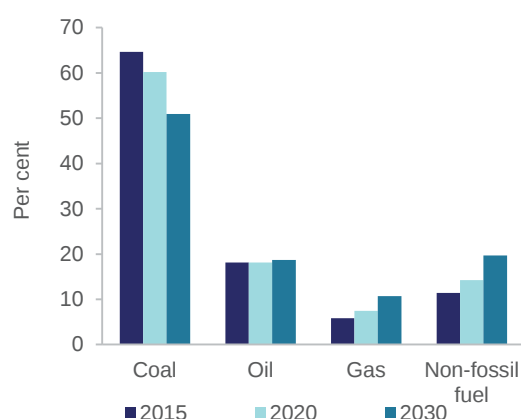
Source: CHINAGEM

Figure 24 shows the shares of all fuels consumption in the primary energy mix and in the electricity generation mix over time under the composite scenario. From 2015 to 2030, the share of coal consumption in the energy mix reduces from 65 per cent in 2015 to 51 per cent in 2030. This decline is balanced by an increase in the gas share from 6 per cent in 2015 to 11 per cent in 2030, and an even greater increase in non-fossil fuels from 11 per cent in 2015 to 20 per cent in 2030.

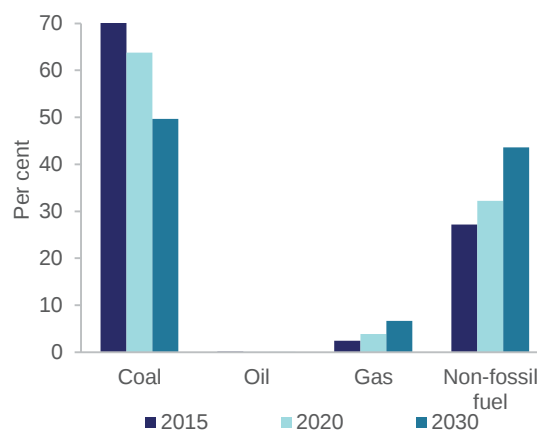
In the electricity generation mix, gas remains a minor input, growing to only 7 per cent by 2030. The main growth area is in non-fossil fuels, which increases to 44 per cent of the electricity generation mix in 2030, up by 17 percentage points in 2015. Coal consumption for electricity generation declines by 20 percentage points to 50 per cent in 2030.

Figure 24: Gas share in the primary energy mix and electricity generation mix in the composite policy, 2015–30

Primary energy mix



Electricity generation mix



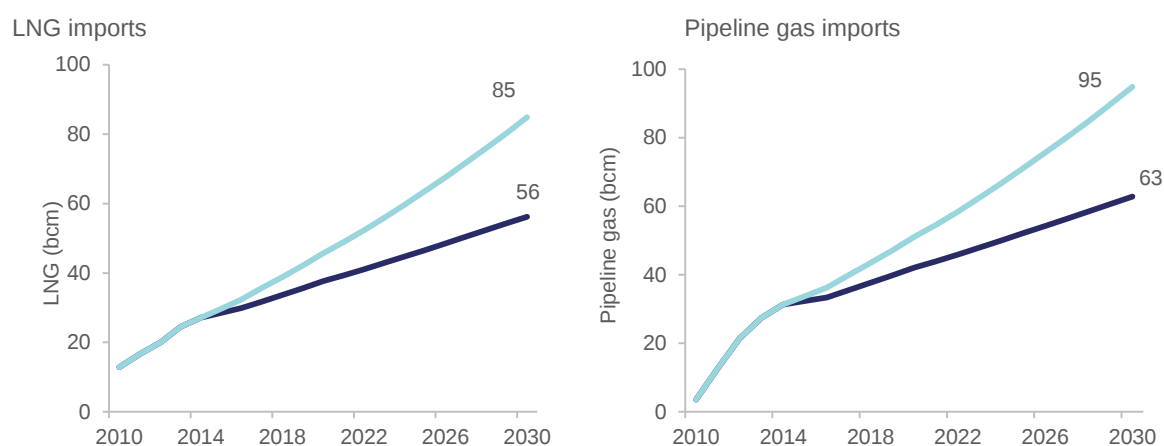
Source: CHINAGEM

Figure 25 shows the effects of the composite policy on LNG and pipeline imports of gas, relative to the baseline. The composite policy stimulates higher demand for natural gas, and a higher share of natural gas in the primary energy and electricity generation mix, resulting in higher imports.

In the baseline scenario, an increase in LNG imports is limited because of the lower total gas demand relative to the new policy scenarios. In the composite policy in 2030, LNG imports are 85 bcm and pipeline gas imports are 95 bcm, which are more than 50 per cent higher than the respective LNG and pipeline gas import in the baseline scenario. Dependency on imported natural gas is 38 per cent higher than in other policy scenarios by 2030 (see [Figure 5.6](#)).

CHINAGEM model has not been designed to predict the sources of China's LNG imports during the forecast period. However, in 2014, the main sources for China's total LNG imports (27.1 bcm) were Qatar (34 per cent), Australia (19 per cent), Malaysia (15 per cent) and Indonesia (13 per cent). It is expected that the share of LNG imports from Australia will increase during the next five years, mainly at the expense of Qatari imports.

Figure 25: Changes in natural gas imports in composite policy vs baseline, 2010–30



bcm = billion cubic metres; LNG = liquefied natural gas

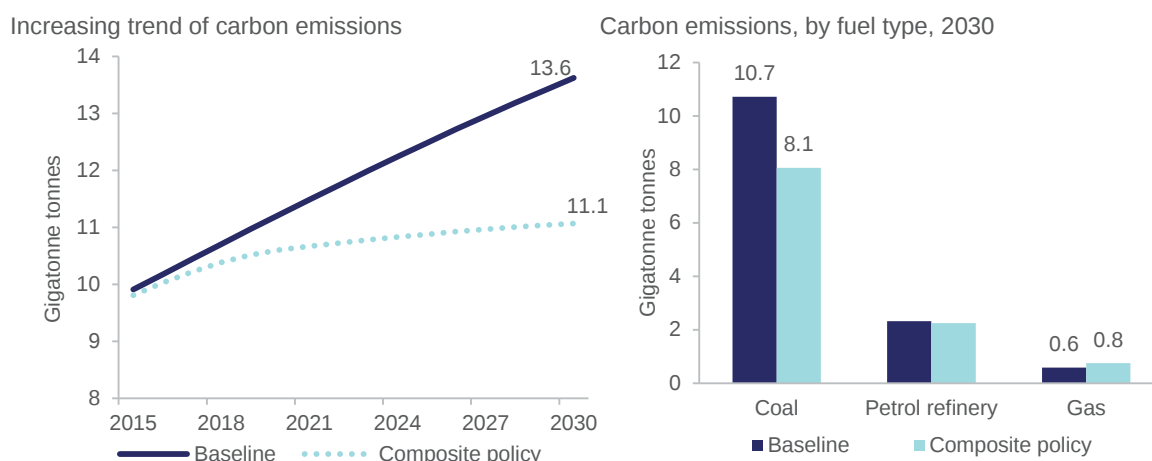
Source: CHINAGEM

Under the composite policy, the share of coal in the energy mix declines, whereas the share of gas and non-fossil fuels increases. This has implications for carbon emissions and greenhouse gas policy. Natural gas combustion is relatively cleaner and emits less CO₂ than other fossil fuels, which makes it favourable in terms of reducing greenhouse gas emissions.

Figure 26 shows that, in the composite policy, total CO₂ emissions grow very slowly from 2020 to 2030, with 0.4 per cent CAGR, compared with around 2 per cent in the baseline scenario during the same period. As a result, by 2030, total CO₂ emissions under the composite policy are 11.1 billion tonnes, which is more than 2.5 billion tonnes below the emissions in the baseline (13.6 billion tonnes). With an annual growth rate of only 0.3 per cent in 2030, total carbon emissions are very close to peaking by 2030, in line with commitments from the Chinese government.

The simulated results also show that, among the total CO₂ emissions, coal emissions reduce to 8.1 billion tonnes in 2030 in the composite policy from 10.7 billion tonnes in the baseline, a reduction of 25 per cent. In the opposite direction, gas CO₂ emissions increase to 0.8 billion tonnes in the composite policy from 0.6 billion tonnes in the baseline, an increase of 29 per cent in 2030.

Figure 20: Changes in carbon emissions and intensity: composite policy vs baseline, 2015–30



Note: China commenced its LNG imports in 2006 and pipeline gas imports in 2010.

Source: CHINAGEM

5. Key findings and concluding remarks

Compared with the baseline scenario, the key outcomes under the composite policy scenario for the year 2030 are that:

- the share of coal consumption in the primary energy mix reduces to 51 per cent (from 60 per cent), the natural gas share increases to 11 per cent (from 7 per cent) and the share of non-fossil fuels increases to 20 per cent from (15 per cent) of the primary energy mix
- natural gas imports grow faster to meet the increased natural gas demand, which allows the import dependency to rise to 38 per cent (from 33 per cent)
- total carbon emissions reduce to 11.2 billion tonnes (from 13.6 billion tonnes).

This study explores key aspects of China's future demand for energy — particularly from LNG — under three distinct policy scenarios:

- scenario one (increasing share of service sector in the economy)
- scenario two (capping coal consumption by 2020)
- scenario three (accelerating unconventional gas production).

The analysis is based on CHINAGEM to simulate the effects of various policy scenarios over time. The forecast mode is used to establish a business-as-usual baseline for China's economy (covering energy and non-energy sectors) through to 2030. The modelling does not reflect or account for abrupt political changes within China, new technological developments in light and heavy manufacturing, or global events that significantly disrupt China's economic performance.

A final policy simulation (i.e. composite policy scenario) integrates the three separate policy scenarios. Compared with the three individual scenarios, the composite policy attains an effective balance between the objectives of strong economic growth, lower carbon emissions, environmental benefits and energy security. The composite policy model points to:

- a higher share of natural gas in China's primary energy and electricity generation mix
- higher LNG imports

- improved air quality because of the lower coal consumption
- lower carbon emissions as a result of the shift from coal to gas.

These beneficial outcomes are matched with an increased trend in GDP growth relative to the baseline scenario.

Compared with scenario one alone, the composite policy predicts higher economic growth, higher income and lower total primary energy consumption. This means there is a reduced need to produce fossil fuels from resources in the economy, and a lower energy intensity. There is higher gas demand, which is supplied by higher indigenous gas production and gas imports.

Compared with scenario two alone, the composite policy shows continued reduction in carbon emissions combined with higher economic growth and higher total energy consumption. There are lower emissions intensity, higher gas imports and a small reduction in indigenous gas production.

The composite policy results in lower total energy consumption and higher gas demand compared with scenario three alone. The accelerated increase in unconventional gas production crowds out a small amount of production of conventional gas. The import dependency of natural gas declines relative to the baseline.

The analysis of oil prices, based on the composite policy, shows that higher oil prices linked to LNG prices lead to lower LNG imports, but incentivise capital investment in indigenous gas production. Table 8 summarises the impact on energy demand of each of the four policy scenarios compared with baseline in 2030.

Table 8: Indicators of changes in energy demand at various policy scenarios in 2030

<i>Demand</i>	<i>Baseline</i>	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>	<i>Composite scenario</i>
Primary energy mix (per cent)					
Coal	60.3	58.9	52.7	60.3	51.1
Gas	7.5	8.1	10.5	7.9	10.7
Non-fossil fuels	14.6	16.0	16.9	14.3	19.7
Electricity generation mix (per cent)					
Coal	63.9	63.7	54.4	64.8	49.7
Gas	5.0	4.8	6.7	4.7	6.7
Non-fossil fuels	31.1	31.4	38.9	30.5	43.5
Carbon emissions (BT)					
Coal	10.7	10.5	8.0	10.7	8.1
Gas	0.6	0.6	0.7	0.7	0.8
Petroleum refinery	2.3	2.3	2.3	2.3	2.3
Gas demand					
Gas consumption (bcm)	365	392	456	391	472
LNG imports (bcm)	56	64	79	50	85
Import dependency (per cent)	33	34	37	27	38

bcm = billion cubic metre; BT = billion tonnes

Source: CHINAGEM and authors' calculations

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