The National and Regional Development of China's Gas Market: Beyond Evolutionary Change?

Report to

Australia China Natural Gas Technology Partnership Fund

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Acronyms

bcm	billion cubic meters
bn	billion
BREE	Australian Bureau of Resources and Energy Economics
CBM	coal bed methane
cms	cubic meters
CTG	Coal to gas
FYP	Five year plan
MEP	Ministry of Environment Protection
MOF	Ministry of Finance
MLR	Ministry of Land and Resources
mtce	million tons coal equivalent
NDRC	National Development and Reform Commission
sce	standard coal equivalent
SNG	Synthetic natural gas
tcm	trillion cubic meters
tn	trillion

SUMMARY REPORT

The Evolution of China's Energy System

China has experienced very rapid growth in the usage of natural gas over the past decade, and also in the use of renewable sources of energy. In both cases this has been from a small base, and has been in the context of an energy system that remains heavily reliant on coal and oil. In 2012, 85.2% of China's energy consumption was provided by coal or oil, with coal being the dominant source at 66.6%. Indeed, China's reliance on coal in 2012 was only marginally lower than a decade earlier, with the rise in other fuels mainly substituting for the reduction in the oil share.

Thus, the past decade has been one of gradual evolution of China's energy system, even though it has implied rapid growth in both natural gas and renewables from a relatively low base. Between 2002 and 2012, the use of natural gas rose by 17.3% per annum, but in 2012 gas only accounted for 5.2% of China's energy consumption, less than one quarter of the global average. Energy provided by renewables – notably hydro, nuclear and wind – grew by 11.3% per annum over this period, and in 2012 provided 9.4% of all energy consumption.

Until recently, the expectation has been that this gradual evolution would continue. For example, the energy development component of the 12th Five Year Plan (FYP) (2011-15), released by the State Council on 1 January 2013, set a target for total energy consumption in 2015 of 4 billion tonnes (standard coal equivalent). This implies an increase in total energy consumption over the period of 4.3% per annum. The Plan also set targets for the share of natural gas and renewables in this total energy consumption in 2015 of 7.5% and 11.4% respectively, with the proportion of coal falling to 65% by 2015. These imply continued strong growth in the usage of natural gas (16.2% per annum) and in renewables (10.3% per annum), but also continued growth in coal use (3.3% per annum). Even on this plan, about 81% of China's energy would still be provided by coal and oil in 2015.

Beyond Evolutionary Change: The Pollution Shock

Several recent developments have raised questions about whether this continuing evolutionary strategy is appropriate for China, and whether more abrupt changes might be both required and possible. One such development, which is not the subject of this report, is the sharp reduction in unit costs being achieved in wind and solar energy in China, as a result of economies of scale and learning by doing. This continuing trend is starting to make these fuel sources more competitive with coal in power generation, especially if the environmental costs of coal use are taken into account.

Another factor, which is central to this report, is the fundamental change which is taking place in the global gas industry, driven by a sharp expansion in potential medium-term supply. A key factor here is the dramatic growth in US shale gas production, and the increasing likelihood of substantial LNG exports from the US, as well as the large reserves of shale gas in China. There has also been increasing utilisation of conventional gas resources and coal seam gas, for example in Australia, while Russia and other countries are actively developing export markets in East Asia and elsewhere. These developments offer the prospect that, after 2015, China could access greatly increased supplies of natural gas at reasonably competitive prices.

But certainly a major factor is the escalation of China's air pollution problem to a major economic, social and political issue within the country in 2013 – which we refer to as the 'the pollution shock'– and the Government's emerging strong response to this issue. During 2013, the hazardous levels of air pollution across much of China became a matter of deep concern for ordinary citizens throughout the country, and especially in the large cities. This concern was sparked particularly by the events of January 2013, when thick smog and haze blanketed Beijing and covered 2.7 million square kilometers of the country, affecting more than 600 million people. These events, together with the recurrence of severe air pollution in many parts of the country throughout the year and the growing awareness of the health and other risks of such pollution, have generated an intense focus on this issue and compelling pressure on Government to take effective action.

China has long had severe environmental pollution, including poor air quality, and the 'pollution shock' is not so much the further deterioration of air quality but the development of this as the central political issue which the Government must address. The fact that in January 2013 in many areas of China, including Beijing, it was hazardous to go outdoors, seems to have triggered a fundamental change in the national mood. All the signs are that the Government realizes that it has 3-5 years to make a serious impact on air quality or it will face growing popular resistance. It also appears to recognize the complexity of this challenge, given that the roots of the high pollution levels lie in the current development model and in particular in an energy system based on coal and oil. An early improvement in air quality is not going to be achieved by continued evolution in China's energy system over the period to 2030. A more vigorous response will be required.

The Emerging Response to the Pollution Shock

The Government's full response to the pollution shock is still emerging, but the key element of the response to date has been the *Action Plan for Air Pollution Prevent and Control* (2013-17), issued by the State Council on 10 September 2013, with some follow up plans for specific cities, regions and industries. The Action Plan aims to achieve a marked improvement in air quality over the five years to 2017, with a particular focus on the three key regions in the heart of China: the Beijing-Tianjin-Hebei region, the Yangtze River Delta and the Pearl River Delta. The Plan includes targeted reductions in emissions of fine particulates with the aim of substantially reducing pollution in the three regions. In particular, mandatory targeted reductions in annual average concentrations of PM2.5 (based upon unpublished 2012 figures) are to be achieved by 2017 as follows:

- Beijing: 25% reduction (60 μg/m3 PM2.5 target set for Beijing as well as a 6 million motor vehicles cap);
- Yangtze Delta Region: 20% reduction;
- Pearl River Delta: 15% reduction; and
- 10% reduction for PM2.5 and PM10 in other key cities.

The Plan recognises that achieving these and other targets requires both a transformation of the energy system and direct action to eliminate pollution. For the first time a ban has been imposed on new coal power plants in the three key regions, and there are to be sharp cutbacks in coal consumption and steel production in the three regions. For example, steelmaking capacity in Hebei province, which produces about one quarter of China's steel, will be reduced by 80 million tonnes by 2017. This is equivalent to about 10% of China's steel production, although the impact on production will be limited by the extent of overcapacity in the steel industry. Most polluting heavy vehicles (yellow labelled) are to be removed from three key regions by 2015 and nationally by 2017. The Euro V equivalent fuel standards (petrol and diesel) will be introduced in the three key regions in 2015 and nationally by 2017. Non-fossil energy resources will increase to 13% of total energy consumption by 2017, by comparison with 9.4% in 2012 and a 12th Plan target of 11.4% for 2015. There will also be a further increase in emphasis on natural gas, as noted below. Increased mechanisms for provincial and ministerial cooperation on air pollution will be put in place (recently evidenced by the Beijing-Tianjin-Hebei agreement with Shandong).

As with any such plans, a key challenge will be implementation, monitoring and enforcement. There are signs that the Government is really serious about the implementation of this Plan. Since 2012, the central and provincial governments have installed 668 air quality observation stations across 114 large and medium-sized cities. Many of these stations are now providing real time publicly available data on air quality, which will keep the issue in public view. The Central Committee of the Chinese Communist Party decided on 10 December 2013 that the performance assessment criteria for local governments and officials will be revised, to reduce the weight of GDP and income growth in the assessment and raise the weight for pollution control, environment and resource protection. This will shift the incentives facing local officials. In order to reinforce the official performance measures, local governments and officials have been set air quality targets with improved consistency around standard measuring procedures and with fines for failing to meet targets. For example, in late 2013 Liaoning Province fined several cities, including Shenyang and Dalian, RMB 54 million for failing to meet air quality targets. Finally the Action Plan announced that there would be 'naming and shaming' of the ten worst and the ten best cities on a monthly basis. These measures amount to a serious portfolio of enforcement instruments.

Natural Gas in the Response to the Pollution Shock

The further exploitation of natural gas plays a substantial part in the Government's response to the pollution shock, and the Action Plan builds upon the *12th Five Year Plan for Natural Gas Development*, which summarises this role as follows:

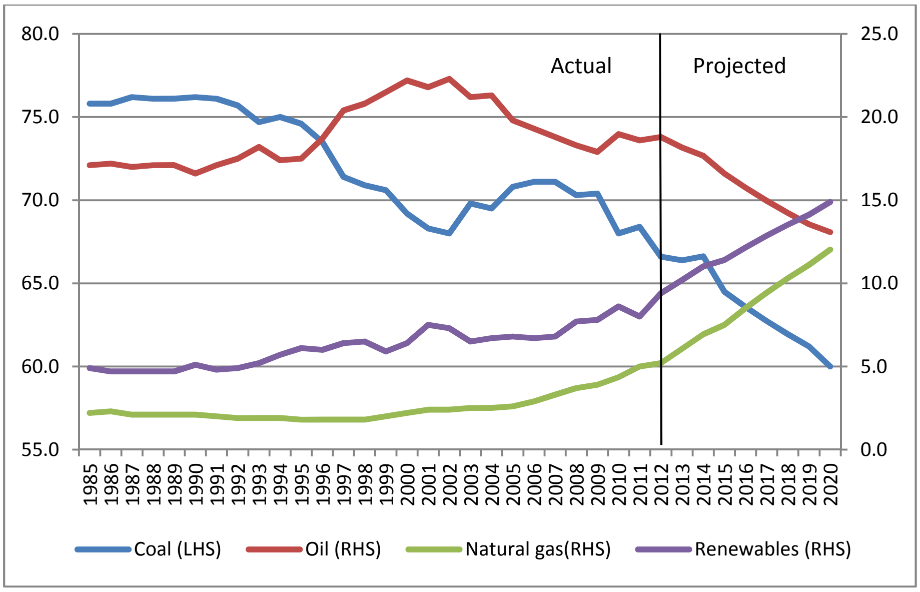
> *'Accelerate the development of natural gas and renewable energy in order to realize a clean energy supply and diversified energy mix. Combine national natural gas pipeline networks, regional pipeline networks, LNG terminals, gas storages and other natural gas distribution projects to strengthen natural 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''.*

More specifically the Action Plan specifies that, in the three key regions, natural gas is to gradually replace coal by 2017 in power stations, industrial furnaces and thermal heating plants, and that gas power plants are to be used to supply peaking power. Gas supplies in the three key regions will be provided by an additional 150 billion cubic metres (bcm) of transmission pipelines. It is specified that coal to gas expansion needs to ensure strict enforcement of environmental controls and the protection of water resources should be tightly monitored. There is also an expressed intention to continue reforms in natural gas pricing to ensure a rationale pricing system is established in line with other energy sources.

Scoping the Implications for the Gas Market

In addition to documenting the Government's emerging response to the pollution shock and placing it in historical and regional context, this report sets out to assess the practicality of, and the implications of, achieving an abrupt change in China's energy structure by 2020. Case studies of Guangdong and Beijing will be used to throw light on the issues involved. At this stage, it is too early to be at all definitive about the Government's plans, which are still being developed and about which there are incomplete and sometimes conflicting indications, much less about the implications of those plans. The changes are to be achieved much more by command economy methods rather than through the operation of price-clearing markets, so limiting the relevance of standard economic modelling. Given this uncertainty we define one specific scenario, illustrated in Figure 1 and documented further in Paper 5, for such an abrupt change, and explore its practicality and implications.

Figure 1 Share of total energy consumption by fuel group, China, 1985-2012 (actual) and 2012-2020 (scenario projection), %



Source: China National Statistical Bureau to 2012, and projections of the authors.

The scenario we test involves a more abrupt reduction in the share of coal and oil in total energy consumption as a result of implementation of the Action Plan and follow-up measures, with an enhanced move to natural gas and renewables, and a further slowing of overall energy consumption. In this scenario, overall energy consumption is projected to grow by 3.3% per annum over 2012-20, but the share of energy use met by coal falls to 60% by 2020. As a result energy consumption from coal grows by only 2.0% over 2012-20 and peaks before 2020, while energy use from crude oil also peaks before 2020 and falls to 13% of total energy consumption by that time. Such a scenario, with a stabilisation of the absolute level of coal use by 2020, seems necessary if China is to generate a major improvement in air quality over this period.

The balance of energy use is deliverecd by further strong growth in energy use provided by renewables – hydro, nuclear, wind and solar energy – and by rapid expansion in China's use of natural gas, from about 150 bcm[1] in 2012 to 425 bcm in 2020. This 425 bcm figure is based on advice from sources within the Chinese Government that the revised target for 2020 is likely to be much higher than the previous target of about 300 bcm, and could be as high as 450 bcm. Energy use from renewables in China has been growing strongly – by 11.3% per annum over 2002-12 – as the Government has sought to develop all forms of renewable energy. The scenario assumes a continuation of this expansion, with energy from renewable sources more than doubling its 2012 level by 2020 to provide 14.9% of all energy consumption at that time, with growth over 2012-20 of 9.4% per annum.

The 425 bcm figure for 2020 implies growth in gas use of 14.7% per annum over 2002-20, by comparison with 17.3% over 2002-12. But a decade ago China's gas use was starting from a very low base (less than 30 bcm in 2002) so that rapid growth rates could be readily achieved. The task of adding some 300 bcm to China's energy use by 2020 is indeed a challenging one, and implies that 12% of China's energy use comes from gas in 2020. Three types of question arise about the achievability of such a target:

- Will supplies of natural gas, whether locally produced or imported, be available to China to achieve such an expansion of gas usage? If so, will China have in place the infrastructure – in terms of pipelines, LNG facilities and distribution networks – to enable such a level of gas use?
- In what sectors of the economy would such increased gas use take place, and will there be an adequate level of demand for natural gas in these sectors?
- At what price will the large supplies of natural gas be available, and will the Chinese price system (both economic and political) be able to handle such growth in a cleaner but higher priced source of energy?

In this report we set out to provide preliminary answers to these questions, both through overall analysis of the issues and through the case studies of Guangdong and Beijing. It is likely to be in the national capital and in the southern province of Guangdong that the attempt to create a clean, low carbon economy will be tested in most detail in the immediate future.

Gas Supply: Domestic Production

In 2012, over 70% of China's gas consumption was supplied by domestic production, and imports of natural gas by pipeline and of LNG together supplied less than 30%. In terms of assessing the supply side of an expansion of gas consumption to 400-450 bcm by 2020, key issues relate to the prospects for expanding both domestic production and imports.

In the Government's planning prior to the pollution shock, much attention has been given to the growth of non-conventional gas supplies such as shale gas, coal bed methane (CBM) and to gas produced by coal gasification (SNG). The 12th Five Year Plan set ambitious targets for these sources for 2015: 6.5 bcm of shale gas, 30 bcm for CBM and 15-18 bcm for SNG. But the problems facing a

[1] The official preliminary NSB figures give a gas consumption figure for 2012 of 141 bcm, but other sources suggest that a figure of 150-160 bcm may have been reached.

rapid increase in each of these sources of unconventional gas have become more widely realised, both internationally (e.g. Yang and Jackson 2013; IEA 2013a) and in China.

China has the largest technically recoverable shale gas resources in the world, and would like to emulate the US shale gas revolution. But China's shale gas resources are much more deeply buried than those in the US (up to 6,000 metres below ground) and are generally in more mountainous or arid regions. It is not yet clear what technologies will be effective in these circumstances and China's national companies have little expertise in this area. Although they are partnering with selected international companies, 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.

In spite of the fact that the Government has introduced a subsidy of 0.4 yuan/m^3 (USD 2/MBtu) for gas produced by the end of 2015, this seems likely to apply to modest rather than large scale production, which may not occur until later in the decade. In its *World Energy Outlook 2013* forecasts (IEA 2013b), the IEA argues that China is unlikely to get close to its official target of 6.5 bcm by 2015 but projects substantial growth to 120 bcm by 2020. In our view there remain considerable uncertainties about whether such a high level of shale gas output can be achieved by 2020. Several observers (e.g. Gao 2012) believe that it will only be in the 2020s that China's efforts to develop large scale shale gas production will bear fruit.

CBM is different, although it also faces some problems in expansion. Given the massive extent of its coal deposits, China's CBM reserves are second only to those of Russia, and have been the subject of research and development activity for 25 years (Gao 2012). The results of these efforts have been somewhat disappointing, with the utilisation rate (the proportion of CBM that is used for effective commercial purposes) being still only around 40%. In 2012 raw production of CBM was 12.5 bcm, but with a 41% utilisation rate actual production was only 5.2 bcm (IEA 2013a). While the official targets continue to assume that 100% utilisation is achieved in the near future, this is widely seen as unrealistic given the historical record. IEA 2013b estimates that the 2015 12th Plan target of 30 bcm will not in fact be achieved until 2020.

Coal-based synthetic natural gas (SNG) has long been seen as a potential option for China, given the large supplies of coal available at low prices in the Xinjiang, Inner Mongolia and Shanxi regions of China. However, it is a capital intensive process and the economics of SNG in China are not yet resolved. The production of SNG also raises serious environmental issues. For example, the process is very water intensive, with each 1000 cubic metres of gas requiring 7 tonnes of water in the standard technology, and China has severe water supply problems, especially in the western and northern regions where the coal supplies are available. SNG production also has other environmental problems, and generates no net reduction in CO_2 emissions relative to the use of coal. It was noticeable that, in spite of the emphasis on expanding natural gas use in the Action Plan, there was a strong note of caution on coal gasification projects, requiring that such projects ensure strict enforcement of environmental controls and tightly monitor the protection of water resources. This suggests that priority will not be given to the development of SNG projects.

While prospects for shale gas, CBM and SNG may be much more subdued out to 2020 than earlier thought, China has substantial reserves of conventional gas and tight gas. These are small in relation to the recoverable reserves of shale gas and CBM (see Figure 1.1 in Paper 1 below), and of the potential for SNG, but they have the advantage of being more readily recoverable. IEA 2013a reports that in terms of proven reserves (reserves commercially recoverable using existing technologies and at current prices) China's reserves of conventional gas are 3.5 trillion cubic metres (tcm), by comparison with 1 tcm for CBM and 0.6 tcm for geological shale gas. With a recovery/reserves ratio of the order of 30, it should be possible to expand production of natural gas from conventional sources further as demand rises.

The other, less remarked, opportunity for expanded domestic production of natural gas in China is tight gas, gas trapped in low permeability reservoirs mainly of sandstone. It is reported that up to 30 bcm of tight gas was produced in China in 2012 (Chen 2013), with the major producer being PetroChina, on its own account from the Sulige field in Inner Mongolia and in conjunction with Shell from the Changbei field in Shanxi. The company is also reported to be in discussions with Exxon about an agreement to develop a large tight gas deposit in the Ordos basin in northern China. PetroChina appear to have made strong progress in developing effective technologies for extracting tight gas in China, and tight gas may well continue to lead the race for the development of China's unconventional gas resources. Zhang Donghui, from the Chinese Academy of Social Sciences, forecast in July 2013 that China would produce 80 bcm of tight gas by 2020 (Bloomberg 2013).

Whatever the final outcome for these competing sources of gas and their related technologies, it is clear that China has a range of options which will be pursued with increased vigour (except perhaps for SNG) after the release of the Action Plan. It seems safe to assume that China's domestic production of natural gas can increase by 8-10% per annum, to 200-230 bcm, by 2020. But much of this production will be in the inland or far west, leaving important infrastructure issues as well as the issue of provision of gas to the booming coastal regions; and China will still require extensive imports of natural gas. In the longer term, the strong prospects for domestic production may give the authorities confidence to invest heavily in the transition to a much more gas-based energy system.

Gas Supply: Pipeline and LNG Imports

In terms of gas imports, China is well placed to benefit from the changes in the global gas markets over the past five years or so. China has close proximity to the two countries with the largest proven gas reserves outside the Middle East, Russia and Turkmenistan (BP 2013), and can access substantially increased supplies of LNG after 2015.

In 2012, Turkmenistan produced 60-65 bcm of gas, of which about one third (20 bcm) was exported to China through the Central Asia Gas Pipeline (IEA 2013a). With proven reserves of 17.5 tcm, Turkmenistan has both the capacity and the incentive to increase exports to China. Subsequent to an agreement between the presidents of the two countries, work is underway to extend both the pipeline capacity and gas exports to China to 65 bcm by 2016. China has also agreed with Kazakhstan to build a pipeline to carry 15 bcm of gas from that country to China by 2015, and construction is underway. Discussions are also underway with other central Asia countries, such as Tajikistan and Kyrgystan, to build export pipelines linked to the Central Asia Gas Pipeline.

The 2,520 km pipeline from Myanmar to China began operation in July 2013, and went into full operation in October 2013. It has the capacity to deliver 12 bcm of gas annually, delivering gas from offshore fields in the Andaman Sea for use in China.

The other main option for pipeline imports into China is from Russia, which has proven gas reserves of 32.9 tcm. Gazprom is the giant government-controlled company which is the largest gas company in the world, producing 487 bcm of natural gas in 2012. Gazprom holds a monopoly over Russia's pipeline exports of natural gas, although a number of independent companies are developing LNG exports. There have been long discussions about the export of natural gas from Russia to China, and in 2009 the two countries reached an agreement for the export of up to 68 bcm of gas, through one or both of two routes: the western route linking to the Altai pipeline in Western Siberia and the eastern Chayanda-Khabarovsk-Vladivostok route linking the Sakhalin and Chayanda fields to north-eastern China. Agreement between the two countries was announced at the G20 meeting in September 2013 on 'all terms and conditions' other than price for a deal to deliver 38 bcm of gas by 2018. While there has been long-standing disagreement about price, Gazprom continues to be optimistic that a deal is imminent, and a negotiated outcome seems likely in due course, in part because of the danger that Russia might miss out on the development of the China market.

In terms of LNG imports, China also has a wide range of options. The most striking case is Australia, where a wide range of new LNG projects are nearing completion and many others are in varying stages of consideration. In its latest Major Projects analysis in October 2013 (BREE 2013), the Australian Government's Bureau of Resources and Energy Economics identified:

- seven LNG projects that were underway, with completion dates been 2014 and 2017, with a total new capacity of 61.8 million tonnes of LNG (85 bcm of natural gas);
- four major LNG projects in the feasibility stage, with total new capacity of 21.6 million tonnes of LNG (30 bcm of gas); and
- six projects which have been publicly announced (including the large Browse project which is considering a floating offshore platform), with total new capacity of 24 million tonnes (33 bcm of gas).

While it is unlikely that all of these projects will proceed, given cost pressures in Australia and competition from other potential new competitors in the LNG market, it is indicative of the potential supply availability. By 2020 Australia is likely to be the world's largest exporter of LNG.

The two major competitors for new Australian projects are likely to be some of the independent Russian producers and the emergence of the USA as a major LNG exporter, while Qatar could launch a new round of LNG projects in due course. With Gazprom having a monopoly over Russian pipeline exports, the independents are turning to LNG exports. On 2 December 2013, President Putin signed off on rule changes that would allow Russia's second gas producer, Novatek, and its premier oil company, Rosneft, to launch LNG projects. The Russian Energy Minister indicated that three new LNG plants would commence production before 2020, to take advantage of what is seen as a window in export markets, including in China, at that time.

However, the major uncertainty in global LNG markets over the next 5-10 years will be the extent to which the USA becomes a major LNG exporter. As US production of shale gas has surged over the past five years to meet domestic demand, US net imports of natural gas have fallen sharply, being only about 30% of their 2007 level by 2012. This has led to a sharp debate about whether US exports should be permitted, especially to countries with which the US does not have a free trade agreement (FTA). Four approvals for LNG export to non-FTA countries have been granted by the US

Department of Energy in recent months, and as at 6 December 2013, 23 such applications remain to be considered (www.energy.gov). The total export volume involved in both the approved and pending applications is about 360 bcm. Although many are unlikely to eventuate, this is a large volume of gas in terms of currently levels of global LNG trade. Given the extent of gas production in the US and the low price received by producers, it seems inevitable that in due course this trade will build up significantly and become an important influence on Asian gas markets.

Gas Supply: Infrastructure Requirements

The preceding analysis shows that, if China did actively pursue an aggressive shift in the structure of its energy system towards gas, as exemplified by a consumption target of 400-450 bcm for 2020, there are a wide range of available options on the supply side. But other potential issues are the availability of infrastructure to deliver gas to the final user, the extent of the demand for gas and the price implications of a shift to gas. These issues are of course interrelated, and closely connected to the supply side options.

China's economic system is heavily focused on construction, and indeed on large scale construction projects, and the infrastructure issues may be the ones that it can most readily address. As noted above, the 12th Five Year Plan clearly identified the infrastructure task: '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'. Extensive action seems to be under way, enhanced by the Action Plan and its regional variants, in each of the elements of the infrastructure task identified here.

For example, in terms of LNG supplies, China had six existing import terminals, with a total capacity of 29.4 bcm, at the end of 2012; eight new terminals were under construction in mid-2013, with a total additional capacity of 31.8 bcm; and LNG receiving terminals with over 60 bcm capacity were in the planning stage (IEA 2013a). With the new impetus provided by the Action Plan many of these are likely to materialise and others are being proposed, so that China should have import capacity, in terms of receiving terminals, well in excess of 100 bcm by 2020.

One factor which may limit the pace of the shift to gas is the relatively low level of gas storage capacity in China. Adequate storage capacity is needed to take advantage of the peak shaving possibilities that gas provides, and the Government's draft regulations on natural gas infrastructure indicate that sellers of natural gas should possess reserves of not less than 15% of annual sales volume to fulfil the requirements of seasonal peak shaving. *China Natural Gas Map 5* reports that at the end of 2012, China's existing gas storages provide working gas storage of 7.4 bcm, or about 5% of overall consumption in 2012.[2] They also report that, as at the end of December 2012, 18 new underground gas storages were either being constructed or under feasibility study. If all of these projects were commissioned they would add 32.5 bcm to storage capacity, increasing China's overall gas storage capacity to 40 bcm, providing a 15% reserve level for total consumption of 267 bcm.

[2] Available at http://www.chinagasmap.com/theprojects/gasstorage.htm#

The Use of Gas within China

The next question is whether the demand for natural gas in China will expand sufficiently rapidly to require supply of 400-450 bcm by 2020. As previously noted, in 2012 gas provided only 5.2% of China's energy consumption (less than one quarter of the global average), so that in principle there is ample room for demand expansion. But it is less clear that such a shift on the demand side, requiring growth in demand of 14.7% per annum over 2012-17, can be achieved so quickly.

The *12th Five Year Plan for Natural Gas Development* highlighted the prioritisation of natural gas for energy generation, its use in centralised combined heat and power (CHP) municipal systems, increasing use of gas in industrial production and the promotion of gas for transport, in addition to the use of gas as a residential fuel. The Action Plan seems to endorse and emphasise each of these priorities.

China's use of gas for power generation is low by world standards and the Plan stresses the need to gradually replace coal by gas in power stations in the three regions by 2017, and to increase the utilisation of gas to supply peaking power. The Beijing Action Plan, for example, states that in 2014 the remaining coal-based units at the Goajing power station will be closed down and those at the Huaneng plant will be closed in 2014, with new gas-fired generators operating at the Huaneng plant in 2015. Even a gradual shift towards increased use of gas for power generation would lead to a rapid percentage increase in gas usage. In 2011, gas provided only 2% of the energy used in power generation in China. If by 2020 that share increased to 5% the annual growth in gas usage over the period would be 14-15%.

Gas-based CHP systems, using combined cycle gas turbines (CCGT) where appropriate, are a major opportunity for China and are recognized by the authorities as such. Existing CHP in China is mostly coal-based, integrated with municipal or industrial district heating systems or selling steam to adjacent industrial sites or district heating loops. These systems are often based on old, inefficient coal boilers and heating loops so the energy efficiency and the GHG reduction benefits of this CHP are limited. Modern CHP systems based on gas offer substantial pollution reductions and, in many cases, cost savings as well. The Action Plan emphasizes gas replacing coal in thermal heating plants, and the Beijing Plan indicates that four large natural gas CHP systems will be established in Beijing in the near future.

There is also considerable scope for increased use of natural gas in industry, where energy use is currently dominated by coal. In China gas provides only 2.8% of the energy used by industry, whereas coal provides 55.2% (IEA 2013b). For the world as a whole excluding China, gas provides 27.2% of industrial energy use and coal only 16.6%. This imbalance in China reflects the low availability of gas in China historically and the low price of coal relative to that of gas. As the availability of gas rises and the price of coal rises to reflect its social costs, there is a major opportunity for fuel shifting and the Action Plan clearly targets such a shift. As with power generation, even a modest shift in the gas share, for example to 6-7% by 2020, would require a rapid rate of growth in gas usage in industry.

Other than continued penetration of natural gas as the preferred fuel of choice of households, another important opportunity is in the usage of gas as a transport fuel. An important feature of the Action Plan is for the most heavily polluting vehicles (the yellow labeled vehicles) to be removed from the three regions by 2015 and nationally by 2017. This involves banning about 15 million vehicles, which account for about 15% of the vehicle stock, but some 60% of the discharge of pollutants. As mentioned earlier, there is also a commitment to introduce the Euro V fuel standards (petrol and diesel) in the three regions by 2015 and nationally by 2017, and to upgrade the environmental quality of the truck and bus fleet. While China has made a heavy commitment to electric vehicles, these make limited contribution to reducing pollution while electricity generation in primarily based on coal. In the shorter term, conversion of road vehicles to natural gas offers an attractive option for an immediate reduction in pollution. This is already taking place to a significant degree, and IEA 2013a forecasts that the use of natural gas in transport in China will grow from 12 bcm in 2012 to 39 bcm in 2018, a growth rate of over 20%. One of China's premier gas companies, PetroChina, which is active across all aspects of the gas value chain, is driving the development of NGVs through its subsidiary Kunlun Energy. This includes plans to develop over 1500 LNG filling stations by 2015. The continuing price differential in favour of gas relative to oil products for transportation (IEA 2013a) is likely to spur the growth of NGVs, while also providing supplier companies with the chance to earn a higher margin.

With a continuing strong preference for natural gas as the fuel of choice for households, there thus seem to be strong prospects for growth across all five of these demand categories, if adequate supplies of gas are available at acceptable prices.

Pricing Issues: Domestic and International

In its 2012 review of gas pricing and regulation in China, the IEA argued that the pricing issue is by far the most important issue that China faces as it seeks to expand gas consumption rapidly, as this issue interacts with all the other aspects of this task (IEA 2012). They note that this includes dealing with more expensive imports, incentivising future unconventional gas production and avoiding cross-subsidies between large users and residential users. It is also pointed out that the pricing structure, whereby the upstream and pipeline tariffs are regulated based on a cost-plus approach and differ depending on the end user, must be changed. These issues are well recognised in China and there has been a long history of attempted pricing reforms for natural gas in China, including a recent pilot program in Guangdong and Guangxi (for a review of both of these see Paper 5 below; see also Li et al. 2013).

The existing structure and regulation of gas prices in China has emerged from an historical situation in which China had limited supplies of gas, and hence use was supply constrained. In this situation relatively high prices could be passed on to industrial and commercial users, with residential users and fertilizer producers protected on social grounds. With cost-plus pricing mechanisms widely employed, China now has a multitude of gas prices in a given region, depending on the source of the gas and the method of delivery. For example, IEA 2012 notes that in Shanghai, city gate prices range from US$ 8/MBtu for domestic gas, and US$ 13/MBtu for Turkmen gas to US$ 17-18MBtu for LNG gas from the spot market. Developing a more market-determined system that generates uniform price outcomes across gas sources, is therefore a high priority, but one which will take time to achieve. A substantial correction to residential prices will also be necessary. In most countries, residential prices are higher than industrial and commercial tariffs, because of the extra costs incurred in supplying at the household level, but in China the reverse is true.

The Action Plan continues to emphasise the reform of the energy pricing of natural gas, 'to ensure a rational pricing system is established in line with other energy sources'. But it is clear that these reforms are now intended to facilitate increases in gas usage that are driven by the Government's response to social and environmental factors, rather than by demand and supply responses to market price signals. This is not to say that pricing reforms will slow down. Indeed, now that residential consumers can see the tangible benefits in terms of better air quality from a greater use of gas, it may be easier for governments at various levels to begin to eliminate the cross-subsidies that residential gas users currently receive.

The topic of past and future trends in global gas prices, including the extent to which gas-to-gas price setting will develop to replace oil-linked contracts and whether the high level of East Asian prices will be significantly influenced by emerging US exports, are complex issues that are beyond the scope of the present report. For detailed discussion see, for example, IEA (2013a; 2013b) and EY (2013). It is generally agreed, however, that with substantial supplies of tradeable gas entering the market in the 2015-20 period, especially if US exports increase rapidly, there is likely to be a shift in the demand/supply balance after 2015 and increased resort to gas-to-gas competition as a basis for setting prices. While many factors will affect the outcome for prices for gas delivered to China, the expansion of Chinese demand for imported gas after 2015 is likely to take place in a relatively benign pricing context. Even if it achieves gas consumption of 425bcm in 2020 this will be only about 10% of global gas consumption; if imports provide 200 bcm of this total they will account for about 15% of global imports.

The Relevance of the Case Studies

In such a large and diverse country as China, implementing major policy changes throughout all provinces and regions is a real challenge. China's planning system is geared to this challenge, with the national five-year plans followed by a cascading series of documents at more detailed policy, industry and regional levels. In following the implementation of the air quality Action Plan of September 2013 the various regional implementation plans will be of key importance.

The case studies included in this report cover Guangdong, which includes the Pearl River Delta, and Beijing. The Guangdong case study (Paper 3) brings out the extent to which the shift to natural gas was already under way in the province prior to the Action Plan. The 12th Five Year Plan for Guangdong's Energy Development envisages growth in total energy usage of 26.1% over 2010-15, using mid-point estimates. But coal and oil use is projected to grow by only 7.7%, while planned natural gas use increases by 122% and renewables use by 96%. As a result the share of coal and oil combined in total energy consumption falls from 81.6% in 2010 to 69.7% in 2015. It has been reported that the provincial government approved the province's Action Plan in relation to air quality on 31 December 2013, but the plan has not yet been published and details are not yet available. It will clearly build on the rapid change in the structure of energy use in the province that is already underway.

Recently, Beijing National Development and Reform Commission (NDRC) revealed an ambitious plan for raising Beijing's gas consumption in the next three to four years to facilitate a strategic shift from energy security to energy security plus clean energy use. As noted in Paper 4, the share of gas in Beijing's total energy consumption will rise from current 14% to 35% in 2017, an increase of 21 percentage points and the share of coal will fall from 24% in 2013 to 10% in 2017, a fall of 14 percentage points. As a result, coal use is set to fall by 10 million tons and gas will become the most important source of energy for Beijing. According to 'Beijing Clean Air Action Plan Tasks 2013-2017' published on 2 September 2013, the Beijing Government plans to raise gas consumption from about 10 billion cubic meters in 2013 to 24 billion cubic meters in 2017.

Conclusion and Implications

The central conclusion of this analysis is that the stars seemed to be aligned for the Chinese Government to make an abrupt change in the role of gas in its energy system over the period to 2020, as expressed in gas consumption in that year of 400-450 bcm, as part of its response to the pollution shock. Such a shift would be abrupt in the sense that the 400-450 bcm consumption level for 2020 would be 40-50% higher than most current forecasts for that time, such as those of the IEA in its October 2013 *World Energy Outlook 2013* (IEA 2013b).

The prospects for further growth in domestic gas production are good, perhaps particularly in tight gas, even though each of shale gas, CBM and SNG are not likely to reach their full potential until after 2020. Especially over the period 2015-20 China should be well placed to draw on large scale supplies of imported gas, both in terms of pipeline imports from countries such as Turkmenistan, Myanmar and Russia, and LNG imports from Australia, Russia, Qatar and other countries. These imports should be at acceptable prices as global supply options increase and as the USA becomes a major LNG exporter and impacts on traded gas prices in East Asia. The diversity of sources from which imports are likely to be available should give the Chinese Government some comfort on security of supply issues.

China's proven ability to undertake large construction projects quickly and effectively should ensure that the various types of infrastructure required can be put in place, from national pipelines and LNG terminals to storage tanks and local distribution facilities. If gas supplies are available at reasonable prices, facilitated by further pricing reforms, demand is likely to be forthcoming in each of the key areas – power generation, CHP systems, industry, transport and residential use – especially if this is driven by a strong national strategy.

While the September 2013 Action Plan and the available follow-up documents for the three target regions clearly indicate that the Government is developing such a strategy, China is a complex country facing many different challenges at this time and persistent implementation over time is difficult. There are also many vested interests, for example among the coal companies and the large state-owned enterprises, which are likely to oppose such an abrupt shift. The Government has also found it difficult to achieve targeted changes in the structure of the economy over the past decade.

The current situation seems to be different, both because serious air pollution is now a dominant feature of Chinese life and because the Government has assembled an impressive suite of monitoring and enforcement measures. But conflicting indicators remain, such as the fact that the Action Plan endorses the 12th Five Year Plan target for the coal share of energy use in 2015 (65%) for 2017, in spite of the fact that both the thrust of the measures it contains and the overall intent imply a more rapid reduction in the coal share. It will only be as more detailed plans are rolled out in 2014 and implementation develops that the real impact of the new strategy will become apparent.

If China were to achieve that scenario outlined here, with the coal share of energy use falling to 60% by 2020 and the combined coal and oil share falling to 73%, this would have a major impact not only within China but in terms of the global effort to combat climate change. Between 1990 and 2011 China contributed 56% of the world emissions from energy use, and is continuing to contribute about 50% going ahead. If China were to achieve this scenario, its energy emissions would peak by 2020 and fall thereafter. This would be a major contribution to the global achievement of the early peak and decline in emissions that is necessary to limit global warming to less than 2°C. Thus an effective Chinese response to its air pollution would have important beneficial effects for the world as a whole.

SUPPORTING ANALYSES

PAPER 1
The Transformation of Global Gas Supply

This paper reviews briefly the background to the transformation in global supplies of natural gas that is under way at the present time, and the prospects for China's domestic production in that context. It reviews selected data on gas reserves, both of conventional gas and of unconventional gas (tight gas, coal bed methane (CBM) and shale gas), discusses the development of shale gas and provides information relevant to future international trade in gas. Each of these factors contribute to shaping the international context in which any abrupt shift in China's usage of natural gas will be played out.

Global Gas Reserves

Gas reserves are assessed on several different bases, and include proven reserves (those which are recoverable given existing technologies and at current prices), known reserves which may require different prices or technologies to be recovered and as yet undiscovered but inferred reserves. The most inclusive measure is technically recoverable reserves, which includes proven reserves, reserves growth and as yet undiscovered reserves. Table 1.1 provides the IEA's estimates of global technically recoverable natural gas reserves, showing 468 tcm of conventional gas and 343 tcm of unconventional gas, of which over half is shale gas. The total reserve figure, 810 tcm, is about 240 times global consumption in 2012 of about 3.3 tcm. This illustrates the massive scale of global gas reserves, and the importance of unconventional gas within the overall reserves picture. Most regions of the world have large gas reserves, with the largest concentration in Eastern Europe and Eurasia.

Table 1.1 Remaining technically recoverable natural gas resources, by type and region, end-2012, trillion cubic metres (tcm)

	Conventional	Unconventional				Total
		Tight gas	Shale gas	Coalbed methane	Sub-total	
E. Europe/Eurasia	143	11	15	20	46	190
Middle East	124	9	4	-	13	137
Asia-Pacific	44	21	53	21	95	138
OECD Americas	46	11	48	7	66	112
Africa	52	10	39	0	49	101
Latin America	32	15	40	-	55	86
OECD Europe	26	4	13	2	19	46
World	**468**	**81**	**212**	**50**	**343**	**810**

Source: IEA (2013b).

Proven gas reserves are less than a quarter of total technically recoverable reserves, in part because much less is known about the conditions under which unconventional gas reserves are recoverable. The estimate of total proven reserves at the end of 2012 published by BP (2013) is 187.3 tcm, or about 55 years at current consumption rates. As Table 1.2 shows, over 80% of these reserves are to be found in twelve countries, headed by Iran, Russia, Qatar and Turkmenistan. Because of the definition of proven reserves, these estimates mainly consist of conventional gas although in the case of the US, for example, production from shale gas fields is well advanced and some shale gas reserves would meet the conditions for proven reserves. Of the top four, China is actively importing from Qatar (LNG) and Turkmenistan (pipeline), and in active discussions with Russian companies in relation to both pipeline and LNG imports. Iran is hoping to resume pipeline exports of gas to neighbouring countries, but has no plans to develop LNG exports to countries further away.

Table 1.2 Proven reserves of natural gas, 12 leading countries, 2012 (tcm)

	Tcm
Iran	33.6
Russian Federation	32.9
Qatar	25.1
Turkmenistan	17.5
USA	8.5
Saudi Arabia	8.2
Venezuela	5.6
Nigeria	5.2
Algeria	4.5
Australia	3.8
Iraq	3.6
China	3.1
Total of the above	151.6
Total proven reserves	187.3
Share of total	80.9%

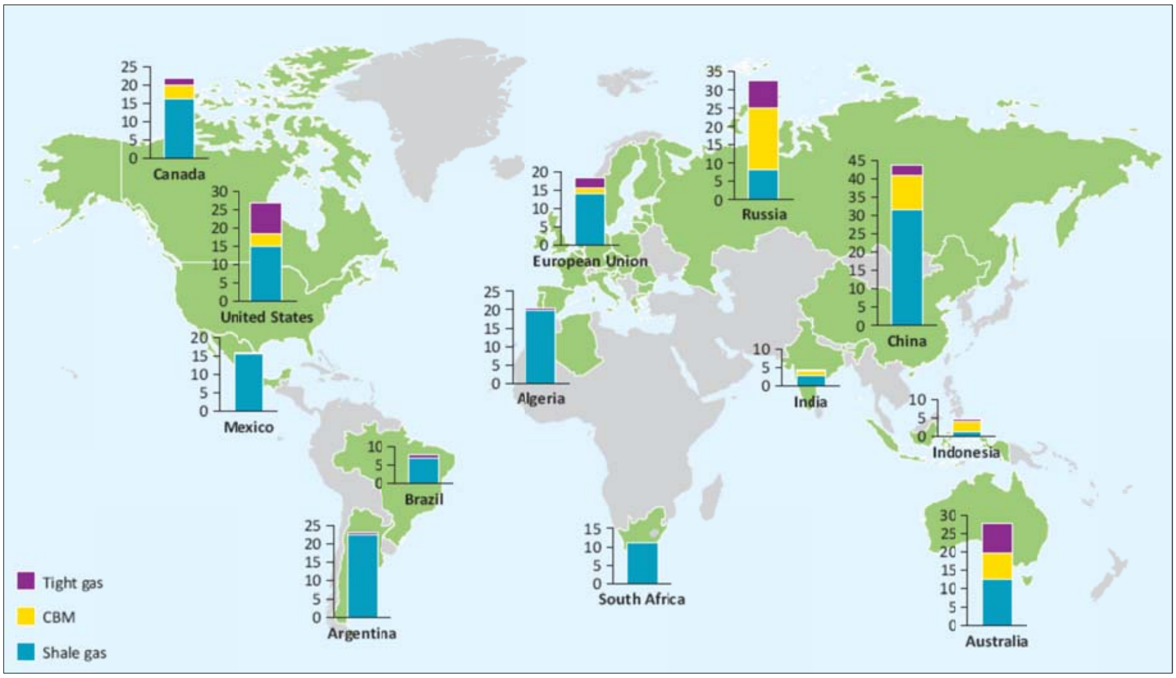
Source: BP (2013).

Figure 1.1 shows IEA estimates of the distribution of unconventional gas reserves by region and by type of gas, at the end of 2012. In the discussions in this report, we distinguish tight gas, which is natural gas that has gathered in small, poorly connected cavities between the rocks (mostly sandstone) from shale gas. Tight gas has been recovered for several decades using hydraulic fracturing, and is sometimes considered as part of conventional gas supplies. With shale gas, the gas has remained trapped in the surfaces of the rock particles in which it has formed and has not migrated to more permeable rock. The production process technology for shale gas is much more complex than tight gas, and because the rock is less porous a much greater volume of liquids is needed to release the gas. Thus the recovery of shale gas normally has more technological and environmental risks than that of tight gas. Global production of these three categories of gas was 560 bcm in 2011, or 17% of total production, with 250 bcm of tight gas, 78 bcm of coal-bed methane and 232 bcm of shale gas, of which 90% was in the USA and Canada (IEA 2013b).

With reserves of nearly 45 tcm, China has the largest resource of these three forms of unconventional gas across the regions shown in Figure 1, with China's reserves being some 35-50% higher than in Russia, the USA or Australia. China's gas reserves are heavily concentrated in shale gas, and indeed it has about twice the shale gas reserves of the USA and some 15% of global known reserves. Its tight gas reserves, which are more readily recoverable, are a small proportion of its overall reserves, although still considerable at about 3 tcm, or 100 times current production levels.

Several features of tables 1.1 and 1.2 and Figure 1.1 are relevant to China's situation. First, the extent of the global reserves of natural gas are generally supportive of a move to greater reliance on natural gas within China's energy structure, as in the longer term gas will remain an abundant resource. This is especially true given that China is still a very modest user of natural gas, accounting for less than 5% of global consumption. Secondly, while shale gas and coal-bed methane will be central to China's long-term position as a gas producer, it has sufficient reserves of conventional gas and tight gas to expand production significantly over the medium term. Thirdly, China is well placed with options for importing gas over the medium term. It has either the reality or good prospects of pipeline imports from two of the world's largest reserve holders (Russia and Turkmenistan), as well as from smaller producers such as Myanmar and several republics in Central Asia. It can also rely on a strong flow of LNG imports from Australia, Qatar, Russia and several other smaller producers.

Figure 1.1 Remaining unconventional gas resources in selected regions, end 2012, tcm



Note: This map is without prejudice to the status or sovereignty over any territory to the delimitation of internatniopnal frontiers and boundaries and to the name of any territory, city or area.
Source: IEA (2013b, p. 116).

The Emergence of Shale Gas in the USA and China

The largest form of unconventional gas reserves in both the USA and China is in shale gas, rather than CBM or tight gas, and it has been the shale gas revolution in the USA which has had a massive impact on the global gas industry. In 2012, the production of natural gas in the USA reached the highest level ever, at 681 bcm, a 5% increase over 2011 and a 25.3% increase over 2007. Over this five-year period, shale gas production in the US grew sixfold from 45 bcm to 264 bcm, or 39% of all production in 2012. This extraordinary growth was driven by the development and application in appropriate circumstances of new technologies, and the relevance of the US experience to China's massive shale deposits is an important issue.

It is again important to stress the distinction between shale gas (where the gas is captured within the structure of the rocks themselves) and tight gas (where the gas is trapped in cavities between the rocks), for the technological challenges are much more acute with shale gas. The geological and the technological issues involved in producing hydrocarbons from shale gas resources remain complex.

Key areas of shale gas technology development in North America are:

- stimulation and completion – hydraulic fracturing of rocks; and
- horizontal well development and associated tools (telemetry and steering tools) and drilling technologies.

There is a growing expertise worldwide and advancements have been made in recent years. Much of the development of the shale gas resources in North America would not have occurred without these two areas of shale gas resource development. Stimulation and completion, and horizontal drilling advances have been critical – in terms of technologies, but are not new. It is auxiliary tools that have been developed in recent years, such as telemetry tools and down hose steering, which have allowed for advancements in and development of conventional shale resources. For example, it is now possible to drill up to 25,000 feet horizontally.

Issues that remain, and require advances, are on the stimulation side – hydraulic fracturing – which has been developed for over 60 years and successfully applied to tight gas, but requires additional development for improved application to shale gas reserves. Initially, the technology was only able to fracture wells in 2-5 places which reduced stimulation and opportunity. Today, up to 25-30 fracture wells can be drilled. They also can go out 6,000 to 8,000 feet, but are limited by well volumes and equipment. These barriers are being removed, and will allow a range of up to 15,000 feet. This would improve the economics and development of reservoirs in an efficient manner.

Lessons learned are not completely finished, and there remains more work to do. On the technology S curve we are now on the steep part of the curve. Originally it took about 20 days to drill one well, but today it only takes around 8 days. More wells can be drilled with one rig. Up to 40 and 50 stages of development are now facilitated by hydraulic fracking technologies. There has been 500 to 600% improvement in the utilisation from each rig due to advances along the learning curve.

New technology drivers that are coming also focus on a smaller footprint from drilling platforms, so there is less surface disturbance per rig. Shale gas development is characterised by an increasing number of surface wells. In conventional oil and gas fields, there may be 10-20 wells, but in terms of shale gas development there can be up to 10,000 wells. Therefore the surface footprint can be significant, so developments in reducing the surface footprint are critical. For example, to get an idea of a typical shale gas reservoir there needs to be 15-20 wells drilled to understand technologies, sweet spot and resources to get data and technical knowhow to develop the site. To illustrate this, from 2005-2011, 50 shale gas wells were drilled in Eastern Europe, whereas in the same period of time, 30,000+ wells were drilled in the US.

Stimulation and fracturing costs need to be reduced. In conventional oil and gas fields, drilling costs are around 60% and completion costs 40%. Shale costs are the opposite, in that drilling costs are about 40%, but the cost of stimulation of hydrocarbons is high with fracking being 60% of the cost.

So these costs need to be reduced. The aim is to switch to around a 60:40 cost ratio so as to reduce number of inputs and costs of stimulation.

Recycling of fracturing fluids is an important consideration especially where there is conflict with land holders and concerns about the contamination of ground water. Typically, drilling sites will encounter 4-10 days of reflow after stimulation of fluids including chemicals, water and some sand (note that only around 35-40% of what is originally pumped into the well comes back out). If it were possible to recycle these fluids (chemicals and water), then the environmental impact (chemicals and water) would be reduced and the economics of development improved. This is especially important in areas in China where water resources are especially stressed and limited.

While experience and technology transfer may somewhat inhibit the development of shale gas in China, from an investment stand point there are major resource and investment opportunities.

Yet so far only 50 shale gas wells have been drilled in China, but we are not aware of any commercial production yet. Each absolute number should be taken with a grain of salt as there is a mix of well qualities, but the key point is that there are sufficient resource opportunities in China.

North America is the test ground or incubator of technology developments – now they need to be taken to China. Many Chinese institutions have been very astute as they are buying into these companies so that they can learn and then take that learning back to China. Not just learning about technologies, but understanding more about rock types and how the different rock types respond to these technologies (how the rock settles, etc.). So implementation of these technologies in China is critical.

CMTC has tied up with Shell, and while China controls the resource, it brings in Shell's knowledge of how to apply these new technologies. This is not just a one-way direction of technologies, as there will be opportunities developed and implemented in China for both parties.

There are two basins in China in particular – the Sichuan Basin and Tarim Basin – where future development of shale gas has been acknowledged across the gas sector. Both are existing oil and gas basins – not surprising as these need a source and that is shale gas. Both basins have similar geology with relatively thick shale fields of 500-600 feet in thickness, ABI of up to 800 and their depth is generally from 8,000 feet to 15,000-16,000 feet with up to 20,000 feet in some areas – which is not that bad. Reservoir properties (thermal maturity and total organic carbon) are within a good range. When looking at the specifics on geological and reservoir data, they are found to be very viable and will be where first shale developments are going to occur with Shell, CNPC and Total. There are five other basins with both marine and non-marine reserves – the latter are older, probably have more clay and are tighter, and the gas might have already leaked. For now the Sichuan and Tarim basins are really the critical areas.

The Sichuan Basin is not surprising because it has already been developed for gas with much of the infrastructure and industry already on site. For example, Connoco bought out Berlington which had gas production investments in Sichuan as did EoG.

Delineating and determining the size of the shale gas resource is essential, but the key is development and transport infrastructure.

Gas resources in China per tonne of rock are probably less than what exists in the US. But there is still a need to develop transport infrastructure to move the gas around. This is less of a problem for Sichuan because of existing infrastructure, but will be critical elsewhere in China.

Transportation refers to the gas resource facilities, but the rest of the capability needs to be developed. For example, sand cannot just be taken out of nearby rivers, specific sands and water sources are required on location along with management of the water resources.

Thus while China has the largest technically recoverable shale gas resources in the world, and would like to emulate the US shale gas revolution, there are a wide range of issues still to be addressed. China's shale gas resources are much more deeply buried than those in the US (up to 6,000 metres below ground) and are generally in more mountainous or arid regions. It is not yet clear what technologies will be effective in these circumstances and China's national companies have little expertise in this area. Although they are partnering with selected international companies, 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.

In spite of the fact that the Government has introduced a subsidy of 0.4 yuan/m^3 (USD 2/MBtu) for gas produced by the end of 2015, this seems likely to apply to modest rather than large scale production, which may not occur until later in the decade. In its *World Energy Outlook 2013* forecasts (IEA 2013b), the IEA argues that China is unlikely to get close to its official target of 6.5 bcm by 2015, but projects substantial growth to 120 bcm by 2020. In our view, there remain considerable uncertainties about whether such a high level of shale gas output can be achieved by 2020. Several observers (e.g. Gao 2012) believe that it will only be in the 2020s that China's efforts to develop large scale shale gas production will bear fruit. In this analysis we do not assume a significant contribution from shale gas to China's natural gas production by 2020, but recognise that it may become a major contributor in the subsequent decades.

Domestic Production from Other Sources

In the Government's planning prior to the pollution shock, much attention has been given to the growth of non-conventional gas supplies such as shale gas, coal bed methane (CBM) and to gas produced by coal gasification (SNG). The 12th Five Year Plan set ambitious targets for these sources for 2015: 6.5 bcm of shale gas, 30 bcm for CBM and 15-18 bcm for SNG. But the problems facing a rapid increase in each of these sources of unconventional gas have become more widely realised, both internationally (e.g. Yang and Jackson 2013, IEA 2013a) and in China. Some of the issues concerning shale gas in China have been discussed above, and we now consider production from other sources.

CBM is different, although it also faces some problems in expansion. Given the massive extent of its coal deposits, China's CBM reserves are second only to those of Russia, and have been the subject of research and development activity for 25 years (Gao 2012). The results of these efforts have been somewhat disappointing, with the utilisation rate (the proportion of CBM that is used for effective commercial purposes) being still only around 40%. In 2012 raw production of CBM was 12.5 bcm, but with a 41% utilisation rate actual production was only 5.2 bcm (IEA 2013a). While the official targets continue to assume that 100% utilisation is achieved in the near future, this is widely seen as unrealistic given the historical record. IEA 2013b estimates that the 2015 12th Plan target of 30 bcm will not in fact be achieved until 2020.

Coal-based synthetic natural gas (SNG) has long been seen as a potential option for China, given the large supplies of coal available at low prices in the Xinjiang, Inner Mongolia and Shanxi regions of China. However, it is a capital intensive process and the economics of SNG in China are not yet resolved. The production of SNG also raises serious environmental issues. For example, the process is very water intensive, with each 1000 cubic metres of gas requiring 7 tonne of water in the standard technology, and China has severe water problems, especially in the western and northern regions where the coal supplies are available. SNG production also has other environmental problems, and generates no net reduction in CO_2 emissions relative to the use of coal. It was noticeable that, in spite of the emphasis on expanding natural gas use in the Action Plan, there was a strong note of caution on coal gasification projects, requiring that such projects ensure strict enforcement of environmental controls and tightly monitor the protection of water resources. This suggests that priority will not be given to the development of SNG projects.

While prospects for shale gas, CBM and SNG may be much more subdued out to 2020 than earlier thought, China has substantial reserves of conventional gas and of tight gas. These are small in relation to the recoverable reserves of shale gas and CBM (see Figure 1.1 above) and of the potential for SNG, but they have the advantage of being more readily recoverable. IEA 2013a reports that in terms of proven reserves (reserves commercially recoverable using existing technologies and at current prices), China's reserves of conventional gas are 3.5 trillion cubic metres (tcm), by comparison with 1 tcm for CBM and 0.6 tcm for geological shale gas. With a recovery/reserves ratio of the order of 30, it should be possible to expand production of natural gas from conventional sources further as demand rises.

The other, less remarked, opportunity for expanded domestic production of natural gas in China is tight gas, gas trapped in low permeability reservoirs mainly of sandstone. It is reported that up to 30 bcm of tight gas was produced in China in 2012 (Chen 2013), with the major producer being PetroChina, on its own account from the Sulige field in Inner Mongolia and in conjunction with Shell from the Changbei field in Shanxi. The company is also reported to be in discussions with Exxon about an agreement to develop a large tight gas deposit in the Ordos basin in northern China. PetroChina appear to have made strong progress in developing effective technologies for extracting tight gas in China, and tight gas may well continue to lead the race for the development of China's unconventional gas resources. Zhang Donghui, from the Chinese Academy of Social Sciences, forecast in July 2013 that China would produce 80 bcm of tight gas by 2020 (Bloomberg 2013).

Whatever the final outcome for these competing sources of gas and their related technologies, it is clear that China has a range of options which will be pursued with increased vigour (except perhaps for SNG) after the release of the Action Plan. It seems safe to assume that China's domestic production of natural gas can increase by 8-10% per annum, to 200-230 bcm, by 2020. But much of this production will be in the inland or far west, leaving important infrastructure issues as well as the provision of gas to the booming coastal regions, and China will still require extensive imports of natural gas. In the longer term, the strong prospects for domestic production may give the authorities confidence to invest heavily in the transition to a much more gas-based energy system.

Prospects for Imports of Natural Gas into China

In terms of gas imports, China is well placed to benefit from the changes in the global gas markets over the past five years or so. China has close proximity to the two countries with the largest proven gas reserves outside the Middle East, Russia and Turkmenistan (BP 2013), and can access substantially increased supplies of LNG after 2015. Figure 1.2 gives some indication of the large scale infrastructure that is in place, under construction or planned in China to facilitate imports of natural gas and to deliver the gas to the markets.

Figure 1.2 Natural gas infrastructure, China

Note: This map is without prejudice to the status or sovereignty over any territory to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: IEA (2012, p. 16).

In 2012, Turkmenistan produced 60-65 bcm of gas, of which about one third (20 bcm) was exported to China through the Central Asia Gas Pipeline (IEA 2013a), which connects to Turkmenistan through Kazakhstan. With proven reserves of 17.5 tcm, Turkmenistan has both the capacity and the incentive to increase exports to China. Subsequent to an agreement between the presidents of the two countries, work is underway to extend both the pipeline capacity and gas exports to China to 65 bcm by 2016. China has also agreed with Kazakhstan to build a pipeline to carry 15 bcm of gas from that country to China by 2015, and construction is underway. Discussions are also underway with other central Asia countries, such as Tajikistan and Kyrgystan, to build export pipelines linked to the Central Asia Gas Pipeline.

The 2,520 km pipeline from Myanmar to China (shown as under construction in Figure 1.2) began initial operation in July 2013, and went into full operation in October 2013. It has the capacity to deliver 12 bcm of gas annually, delivering gas from offshore fields in the Andaman Sea for use in China.

The other main option for pipeline imports into China is from Russia, which has proven gas reserves of 32.9 tcm. Gazprom is the giant government-controlled company which is the largest gas company in the world, producing 487 bcm of natural gas in 2012. Gazprom holds a monopoly over Russia's pipeline exports of natural gas, although a number of independent companies are developing LNG exports. There have been long discussions about the export of natural gas from Russia to China, and in 2009 the two countries reached an agreement for the export of up to 68 bcm of gas, through one or both of two routes, both shown as planned in Figure 1.2: the western route linking to the Altai pipeline in Western Siberia and the eastern Chayanda-Khabarovsk-Vladivostok route linking the Sakhalin and Chayanda fields to north-eastern China. Agreement between the two countries was announced at the G20 meeting in September 2013 on 'all terms and conditions' other than price for a deal to deliver 38 bcm of gas by 2018. While there has been long-standing disagreement about price, Gazprom continues to be optimistic that a deal is imminent, and a negotiated outcome seems likely in due course, in part because of the danger that Russia might miss out on the development of the China market. There were persistent reports at the end of 2013 that a price deal was imminent at about $13 per MBtu at the Chinese border.

In terms of LNG imports, China also has a wide range of options. The most striking case is Australia, where a wide range of new LNG projects are nearing completion and many others are in varying stages of consideration. In its latest Major Projects analysis in October 2013, the Australian Government's Bureau of Resources and Energy Economics (BREE 2013) identified:

- seven LNG projects that were underway, with completion dates been 2014 and 2017, with a total new capacity of 61.8 million tonnes of LNG (85 bcm of natural gas);
- four major LNG projects in the feasibility stage, with total new capacity of 21.6 million tonnes of LNG (30 bcm of gas); and
- six projects which have been publicly announced (including the large Browse project which is considering a floating offshore platform), with total new capacity of 24 million tonnes (33 bcm of gas).

Further details on these 18 projects are provided in Table 1.2. While it is unlikely that all of these projects will proceed, given cost pressures in Australia and competition from other potential new competitors in the LNG market, it is indicative of the potential supply availability. By 2020 Australia is likely to be the world's largest exporter of LNG.

The two major competitors for new Australian projects are likely to be some of the independent Russian producers and the emergence of the USA as a major LNG exporter, while Qatar could launch a new round of LNG projects in due course. With Gazprom having a monopoly over Russian pipeline exports, the independents are turning to LNG exports. On 2 December 2013, President Putin signed off on rule changes that would allow Russia's second gas producer, Novatek, and its premier oil company, Rosneft, to launch LNG projects. The Russian Energy Minister indicated that three new

LNG plants would commence production before 2020, to take advantage of what is seen as a window in export markets, including in China, at that time.

However, the major uncertainty in global LNG markets over the next 5-10 years will be the extent to which the USA becomes a major LNG exporter. As US production of shale gas has surged over the past five years to meet domestic demand, US net imports of natural gas have fallen sharply, being only about 30% of their 2007 level by 2012. This has led to a sharp debate about whether US exports should be permitted, especially to countries with which the US does not have a free trade agreement (FTA). Four approvals for LNG export to non-FTA countries have been granted by the US Department of Energy in recent months, and as at 6 December 2013, 23 such applications remain to be considered (www.energy.gov). The total export volume involved in both the approved and pending applications is about 360 bcm. Although many are unlikely to eventuate, this is a large volume of gas in terms of currently levels of global LNG trade. Given the extent of gas production in the US and the low price received by producers, it seems inevitable that in due course this trade will build up significantly and become an important influence on Asian gas markets.

Table 1.3 New LNG projects, by status, Australia, October 2013

Project	Company	State	Location	Estimated start up	Estimated new capacity (mt)	Indicative cost estimate $m
Committed						
Australia Pacific LNG (trains 1 and 2)	Origin/ConocoPhillips/Sinopec	Qld	Gladstone	2015	9	24700
Gladstone LNG	Santos/Petronas/Total/Kogas	Qld	Gladstone	2015	7.8	18000
Gorgon LNG	Chevron/Shell/ExxonMobil	WA	Barrow Island	2015	15.6	52000
Ichthys LNG	Inpex Holdings/Total	NT	Darwin	2017	8.4	33000
Prelude Floating LNG	Shell	WA	Browse Basin	2017	3.6	12600
Queensland Curtis LNG project	BG Group, CNOOC	Qld	Gladstone	2014	8.5	19800
Wheatstone LNG	Chevron/Apache/KUFPEK/Shell	WA	145 km NW of Dampier	2016	8.9	29000
Total committed					61.8	189100
Feasibility stage						
Arrow LNG Plant (trains 1 and 2)	Shell/Petro China	Qld	Gladstone	2018	8	20000
Bonaparte Floating LNG	Santos/GDF Suez		250 km W of Darwin	2018+	2.4	13000
Gorgon (train 4)	Chevron/Shell/ExxonMobil	WA	Barrow Island	2018+	5.2	12000
Scarborough FLNG	Exxon Mobil/BHP Billiton	WA	220 km NW of Exmouth	2018+	6	14000
Total feasibility stage					21.6	59000
Publicly announced						
Browse LNG	Woodside Energy/BP/PetroChina/Shell	WA	Browse Basin	2018+	12	na
Cash Maple Development	PTTEP Australasia		Timor Sea	2018+	2	5000+
Crux LNG	Shell/Nexus Energy/Osaka gas		700 km W of Darwin	2018+	3	5000+
Fisherman's Landing LNG (train 1)	LNG Limited	Qld	Gladstone	2018	1.5	1500
Fisherman's Landing LNG (train 2)	LNG Limited	Qld	Gladstone	2018+	1.5	500 - 1000
Sunrise Gas project	Woodside Petroleum/ConocoPhillips/Shell/Osaka Gas	JPDA	450 km NW of Darwin	2018+	4	5000+
Total announced na						**24**

Source: BREE (2013).

PAPER 2
Energy Policy and the Pollution Shock: The Developing Response

This report is based on the fact that, while China has for many years recognised that it faces serious environmental challenges, including in air quality, the events of January 2013 and later in the year escalated China's air pollution problem to a major economic, social and political issue within the country in 2013 – which we refer to as the 'the pollution shock'– and the Government's emerging strong response to this issue. During 2013, the hazardous levels of air pollution across much of China became a matter of deep concern for ordinary citizens throughout the country, and especially in the large cities. This concern was sparked particularly by the events of January 2013, when thick smog and haze blanketed Beijing and covered 2.7 million square kilometers of the country, affecting more than 600 million people. These events, together with the recurrence of severe air pollution in many parts of the country throughout the year and the growing awareness of the health and other risks of such pollution, have generated an intense focus on this issue and compelling pressure on Government to take effective action. The 'pollution shock' is not so much the further deterioration of air quality, but the development of this as the central political issue which the Government must address.

This paper provides some background to this issue and to the Government's developing response. It discusses the framework for energy policy in China, in the context of the national five year plans followed by a cascading series of documents at more detailed policy, industry and regional levels; the medium term response to air quality issues in China and the pollution shock itself; and the response to this shock in terms of the September 2013 State Council Action Plan and the follow-up initiatives at different levels.

The Framework for Energy Policy

The past decade has been one of gradual evolution of China's energy system, even though it has experienced rapid growth in both natural gas and renewables from a relatively low base. Between 2002 and 2012 the use of natural gas rose by 17.3% per annum but in 2012 gas only accounted for 5.2% of China's energy consumption, less than one quarter of the global average. Energy provided by renewables – notably hydro, nuclear and wind – grew by 11.3% per annum over this period, and in 2012 provided 9.4% of all energy consumption.

Until recently, the expectation has been that this gradual evolution would continue. In the framework of the national 12th Five Year Plan (2011-15), the energy development 12th Five Year Plan was released by the State Council on 1 January 2013. It set a target for total energy consumption in 2015 of 4 billion tonnes (standard coal equivalent), which implies an increase in total energy consumption over the period of 4.3% per annum. The Plan also set targets for the share of natural gas and renewables in this total energy consumption in 2015 of 7.5% and 11.4% respectively, with the proportion of coal falling to 65% by 2015. These imply continued strong growth in the usage of natural gas (16.2% per annum) and in renewables (10.3% per annum), but also continued growth in coal use (3.3% per annum). Even on this plan about 81% of China's energy would still be provided by coal and oil in 2015. The central targets of this Plan are summarised in Table 2.1.

Table 2.1 Key targets of 12th Five-year Energy Plan (January 2013), billion tonnes of standard coal equivalents (btce) unless stated

	2010	2015	Average growth	Status
Primary energy consumption	3.25 btce	4 btce	4.3%	Forecast
Non-fossil fuel energy of total energy	8.6%	11.4%		Binding
Civil power consumption	4.2 trillion kWh	6.15 trillion kWh	8%	Forecast
Energy consumption per unit of GDP tceTCE/RMB10,000	0.81btce	0.68	16%	Binding
Primary energy production capacity	2.97 btce	3.66 btce	4.3%	Forecast
Coal production capacity	3.24 billion tonnes	4.1 billion tonnes	4.8%	Forecast
Natural gas production capacity	94.8 bcm	156.5 bcm	10.5%	Forecast
Power capacity	970GW	1,490 GW	9%	Forecast

Source: State Council 12th Five-Year Plan on Energy Development, January 2013.

Within this Plan, the development of the natural gas sector is a priority area of the central government's overall energy security policy, but it also carries additional strategic weight, in terms of adjusting the energy structure away from an over reliance upon coal and towards improving energy conservation and higher value added production, as well as reducing urban air pollution and carbon emissions.

China hopes to replicate the experience in the US by exploiting significant unconventional shale gas and coal seam gas resources in the medium to long term. However, in the short term it will need to increasingly augment local supplies with imports, both pipeline and LNG shipments. By 2025, China is expected to be one of the largest gas producers globally.

Greater regional gas price convergence and connectivity are expected due to four factors:

- increasing trade volumes;
- greater short-term trading;
- greater operational flexibility; and
- new regional gas trading between North America and Asia.

It is a complex period for attempting to understand the global and Chinese natural gas sector. Significant changes have occurred over the past five years and it is unlikely that the turbulence in the sector will change. These changes include: the deep and broad impacts of the global financial crisis on energy demand and availability of credit; the rapid expansion of US shale gas supplies; ambitious proposals for the development of unconventional gas supplies; the need to reduce carbon emissions; nuclear constraints, increasing demand for cleaner air in cities; and significant investment in new

LNG projects. All of these changes have produced a complicated and unpredictable gas market with significant growth in demand for gas on the one hand and an increasing diversification in the gas pricing mechanism with emerging signs of a break in East Asia between oil and gas pricing.

Some features of subsequent planning initiatives in China related to natural gas are reviewed below.

Conventional gas industry

In October 2012, the State Council approved the NDRC's and Energy Bureau's 12th Five-year Plan (FYP) to Promote the Development of Natural Gas《天然气发展'十二五'规划》. Eight key priorities in the FYP include 'strengthening the management of development projects, promoting innovation, increasing domestic security of supply, promoting the development of shale gas, speeding up infrastructure construction, improving international cooperation, promoting the efficient allocation and use of natural gas, and improving the gas price mechanism'.

In November 2012, the central government announced a shale gas subsidy of RMB 0.4 per cubic meter which will be in place until the end of 2015. The subsidy is double that offered to coal bed methane.

Unconventional gas industry

China has held two auctions for the development of shale gas blocks. The first included four blocks in June 2011 and the second auction covered 20 blocks in September 2012.

Foreign companies were invited to participate in the second auction so long as they entered bids through joint ventures with local Chinese firms. This strategy was aimed at building technical and system capacity within domestic firms which has been acknowledged as a weakness.

High initial development costs, technological complexity, regulatory gaps, environmental and safety issues and a lack of comprehensive distribution network are the main barriers confronting the development of shale gas in China. According to Zhang Dawei of the Strategic Research Center of Oil and Gas Resources within the Ministry of Land Resources, , 'as shale gas production scales up, problems such as insufficient infrastructure will create bottlenecks for exploitation'.

In order to attract higher levels of investment in the shale gas sector, the central government is considering introducing subsidies and tax incentives to encourage investment.

12th Five Year Plans for Shale Gas and Coalbed Methane

These cover the 'Shale gas of 12th Five-Year Development Plan' and 'CBM 12th Five-Year Development and Utilization'. During the 12th Five-Year Plan (2011-2015) unconventional gas development and utilization shall reach the following 2015 targets:

- New CBM proven geological prospecting reserves will reach 1 tcm, and the CBM output will reach 16 bcm.
- CBM gas drainage will reach 14 bcm.
- The Energy Bureau expects annual natural gas consumption to reach 230 bcm by 2015.

- 13 gas pipelines with a total length of 2054 km and the gas transmission capacity of 12 bcm will be constructed in region of Qinshui Basin, East of Ordos Basin, and north of Henan province.
- Gas utilization amount will reach 8.4 billion cubic meters, with a utilization rate of over 60%, more than 3.2 million residential customers, and the power generation capacity of more than 2.85 million kW.
- Cumulative utilization of CBM will reach 65.8 billion cubic meters, which equals savings of 79.62 mtsce, and will reduce the emissions of carbon dioxide by 990 mtsce.
- Shale gas proven geological prospecting reserves will reach 600 bcm with 6.5 bcm brought into production by 2015. This will require around 1000 wells to be drilled.
- Recoverable shale gas resources will reach 200 bcm.
- Annual output of shale gas will reach 6.5 bcm.

Coal to gas (CTG)

In 2012, China announced four pilot coal-to-gas (CTG) projects in Inner Mongolia and Xinjiang worth around RMB 90 billion with a capacity of around 15 bcm a year by 2015. A further 15 coal to chemical projects were also announced in mid 2012. A CTG plant typically costs around RMB 4-6 billion per bcm of gas capacity.

A major challenge for CTG is its high use of water resources. For example, the direct liquefaction of coal needs approximately 7 tons of water for each ton of coal used and the indirect liquefaction process needs 12 tons. It was estimated that the 15 coal to chemical projects will require around 1.1 billion tons of water, and thus raise the coal sectors consumption of water to 12 tons.

Datang Power has been involved in the CTG sector since 2007 when it imported gasification technology from Europe. Datang Power's first CTG plant started operations in 2012 in Inner Mongolia with a 1.33 bcm/year capacity to supply Beijing.

Unconventional gas sector

In early 2012, the Chinese Ministry of Land and Resources (MLR) announced estimates of 25.08 tcm of unconventional on-shore gas reserves. The resources are yet to be commercially exploited and are reportedly more 'complicated' than those found in the United States due to the geological conditions, depth of the reserves and the remoteness of the locations. Both hard (fracking, horizontal drilling) and soft technological issues, a lack of industry experience, limited water resources and insufficient piping infrastructure are other reported barriers. Another challenge for the sector is the low wholesale and retail prices for gas due to state subsidies. Firms involved in the development of gas complain that the low prices inhibit investment in the sector.

The Plans project that, by 2020, unconventional gas output is targeted to reach 120 bcm, including 80 bcm of tight gas, 30 bcm of coal-bed methane and 10 bcm of shale gas. It is projected that overall demand will grow to around 230 bcm by 2020 so that imports make up around a half of total demand. Estimates of gas consumption for 2030 vary considerably but are generally between 300-450 bcm with tight gas making up around 100 bcm of output per annum. Tight gas has been the most successful area for development, especially the Inner Mongolian fields. Tight gas production is expected to exceed 50 bcm by 2015 and continue to expand through to 2020.

Shale gas

Chongqing Municipality and Sichuan Province are probably the most advanced in potentially tapping into China's shale gas reserves estimates of 2.05 tcm with initial pilot projects commencing development in July 2012. Chongqing has also set up a 2015 target for shale gas production to reach 1.3-1.5 bcm per annum.

There are reports in the Chinese media of noted shale gas production targets of around 6.5bcm by 2015. Depending upon tracking of progress in meeting this target, the 13th Five-Year Plan (2016-2020) may include specific details of production targets and commercialisation of the sector. Expectations for shale gas development vary from around 60 to 100 bcm of annual production by 2020.

In 2012, the Ministry of Land Resources announced the first two auctions for shale gas drilling rights in May and October. The initial auction attracted four companies with over 70 domestic companies registering their interest for the second round, including the big three of CNPC, Sinopec and CNOOC. The drilling auctions included 24 shale gas blocks across the country.

By early 2013, China is reported to have completed 63 shale gas wells. In order for China to meet its 2015 target of 6.5 bcm of shale gas output, over 100 wells will need to be drilled each year. Chinese investors are seeking overseas opportunities in United States, Canada, Australia and Poland, in the shale gas sector to gain access to knowledge, experience and technologies.

The energy diversification and increasing supply options for China are likely to have significant implications for Australian gas investments on several fronts in China.

First, the strong growth of cheaper pipeline gas supplies from Central Asia combined with the potential of a ground breaking deal with Russia could seriously affect the price of future LNG shipments to China. Second, depressed US gas prices on the back of the shale gas boom are already entering Asian supply agreements (2012 South Korea @Henry Hub price). The potential expansion of LNG exports from the US will increase the likelihood of finally breaking the LNG-oil linked price in the region. Third, the mid to long-term over supply arising from Chinese shale gas will have a critical impact especially on the domestic regional level where shale gas supplies are located but will quickly spread nationally. In the medium to longer term, the implications will encompass Taiwan, South Korea and Japan.

In the short term, suppliers will benefit (at any price) for two main reasons: i) strong demand in China especially as air quality pressures increase on Chinese coastal cities; and ii) the need to fill the immediate energy vacuum left by Japan's 'phase out' of nuclear and the medium-term growth in demand due to remaining safety concerns across the Asian region that will demote nuclear as a low carbon alternative.

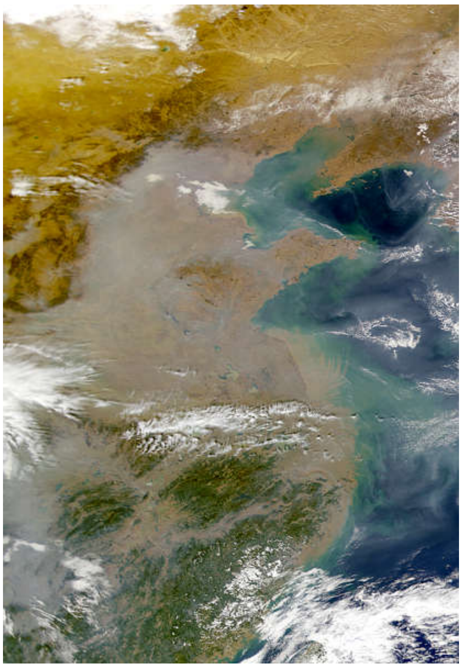
The Pollution Shock

According to World Bank estimates, 16 of the world's 20 most-polluted cities are in China. The single largest contributor to the poor air is a heavy dependence upon coal-fired power plants for around 90% of China's electricity generation. The ADB (2012) estimates that poor air quality results in half a million premature deaths in Asia alone per annum. The levels of damaging air pollutants, particularly fine particulates (PM2.5) that cause respiratory and heart disease, are high and rising in most Chinese cities. Despite heavy spending attempting to clean the air prior to the 2008 Olympics, ozone levels in the national capital doubled US EPA levels, whilst concentrations of PM2.5 are six to ten times (ranging from 96.5 µg/m-3 to 154.3 µg/m-3) US EPA levels (Chen and Yao 2008).

The World Meteorological Organization (WMO) and the International Global Atmospheric Chemistry (IGAC) (2012) report *Impacts of Megacities on Air Pollution and Climate*, appropriately released in Beijing, argued that the health impacts of poorly planned and developed cities will be serious. According to lead author, Zhu Tong, rapidly expanding cities with 'poor planning and few pollution-reduction measures…[are] having serious consequences on the environment and public health'.

The major factor escalating China's air pollution problem to a major economic, social and political issue were a series of crisis levels within the country in 2013. During 2013, the hazardous levels of air pollution across much of China became a matter of deep concern for ordinary citizens throughout the country, and especially in the large cities. This concern was sparked particularly by the events of January 2013, when thick smog and haze blanketed Beijing and covered 2.7 million square kilometers of the country, affecting more than 600 million people. These events, together with the recurrence of severe air pollution in many parts of the country throughout the year and the growing awareness of the health and other risks of such pollution, have generated an intense focus on this issue and compelling pressure on Government to take effective action.

Figure 2.1 Satellite image of air pollution, China, 2013



Source: SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE, available at http://eoimages.gsfc.nasa.gov/images/imagerecords/53000/53490/S1999324040624_md.jpg

PM2.5 refers to airborne particles 2.5 micrometres or less in diameter. In Beijing, PM2.5 concentrations average between 100 and 150 micrograms per cubic metre. PM2.5 became a household term in 2012 following growing displeasure at the yawning gap between Beijing city health pronouncements and those of the US embassy. Typically, the US embassy readings were at warning levels whilst Beijing city was pronouncing 'good' air quality. Part of the explanation for the discrepancy was that Beijing city was basing readings upon the coarser and less dangerous PM10 figures that were averaged out across the city, while the US embassy measured at one point on their grounds, but were measuring the more dangerous PM2.5 concentrations.

According to UCLA's Andre Nel, for every 10-microgram-per-cubic-metre increase of PM2.5 concentrations, mortality levels rise by 1%.

In 1996, China introduced important legislation aimed at reducing sulphur dioxide and carbon monoxide levels in cities by requiring the use of scrubbers in coal power plants and tightening up vehicle emissions.

Then in early 2012, the State Council introduced legislation aimed at measuring and reducing ozone and PM2.5 concentrations in every Chinese municipal and provincial capital, as well as the three major economic regions of Pearl River Delta, the Yangtze River Delta and the Beijing-Tianjin-Hebei Region. The cost of establishing the monitoring network was estimated at around RMB 520 million.

By the end of the 12th FYP period (2011-15), China plans to establish a national air quality monitoring network across all its 113 major cities at prefecture level and above. By 2012, the MEP initially planned to have 138 monitoring stations in 74 cities with a further 195 being trialled for PM2.5. So that nationally a total of 496 monitoring stations were to be in operation by the end of 2012 with cities encouraged to make the data public. However, by early 2013, the monitoring network was only publicly accessible in 60 cities. Moreover, the Beijing figures only included very simple aggregated figures for the source of pollution, listing contributions from vehicles, coal power plants, industry, construction dust, agriculture and regional sources. Without more detailed monitoring and publicly available data, more detailed analysis and understanding of the sources will be slower in being realised.

China will require cities to meet a national air quality standard by 2030. The standard includes daily PM2.5 limit of 75 mcg per cu m, with an average annual ceiling of 35 mcg per cu m.

In 2011, the Ministry of Environmental Protection (MEP) released a consultation draft of the technical rules relating the daily publication of an Air Quality Index (AQI) which included health warnings, recommended measures and suggestions for vulnerable groups. Some cities such as Shanghai and Guangzhou are already using parts of these systems, with color-coded maps and warnings on their websites. However, most other cities continued to release the initial AQI rankings of 'good', 'moderate', or 'poor' air-quality. In December 2012, the MEP released a 12th Five Year Plan for tackling air pollution, including 'sulphur dioxide, nitrogen oxides, industrial smoke, dust and volatile organic compounds from key industries, as well petrol vapour recovery at filling stations and eliminating vehicles failing to meet basic emissions standards'.

The city of Beijing already has an action plan for reducing air pollution in the city. For example, between 2012 to 2020 PM2.5 levels need to decrease by 15% drop on 2010 figures by 2015, decline by 30% by 2020, and reach the national standard of an annual average of 35 micrograms per cubic metre by 2030. In December 2012, Beijing made an important first step in releasing its plan for implementing the 2030 goal of clean air. According to the plan, on days of dangerous air quality, susceptible groups and schools will be advised to avoid or cease outdoor activities. In addition, government and private use of vehicles will be constrained. The plan also includes actions for reducing polluting industrial activity.

Beijing already has a network of 35 PM2.5 monitoring stations spread across the city with the pilot data published daily online. From 2013, the MEP plans to formally adopt PM2.5 as a measure of local air quality based upon the network of monitoring stations. The legislation set a mandatory annual target of a 2% reduction for each category of air pollutant commencing from 2016. According to Peking University's Shao Min, unlike SO_2 and CO_2, which are typically point source pollutants, PM2.5 and ozone are 'secondary pollutants that are formed by chemical reactions between a range of different precursors in the atmosphere' (Qiu 2012). As a result, dangerous levels of PM2.5 and ozone are more likely due to diffuse sources across a region. Shao argues that the 'very severe and complex' nature of this air pollution, therefore, requires a structural shift in energy generation, transport and even urban planning and development . Moreover, such changes need to be transboundary in design to be effective, so that they encompass the whole region. In the case of Beijing, which already has the strictest air quality standards, this requires greater cooperation and agreement with neighbouring Hebei Province and Tianjin City.

There are several priorities that need to be addressed so that China can seriously tackle the city's air pollution. First, the prompt provision of public access to the raw air-quality data is necessary to ensure they are accurate and comprehensive, as well as restore confidence in the system. Second, better understanding is needed of the leading causes of pollution and the development of plans and targets for reducing the sources and their growth. Third, public health warnings need to be regularly issues so as to reduce behaviour on their health and avoid activities that exacerbate the pollution.

China's Developing Response to Air Pollution

The 12th Five Year Plan and associated measures

In 2012, MEP, NDRC and MoF published the *12th Five-Year Plan on Air Pollution Prevention and Control in Key Regions*, which was unique in several respects:

- It was the first national level comprehensive response to air pollution.
- It covered 119 cities across 19 provinces in three key regions Beijing-Tianjin-Hebei, Yangzi River Delta and Pearl River Delta.
- Coverage was: half population; 14% of land area; 71% of GDP; half of coal consumption.
- Targets were:
    - All cities were to reduce ambient concentration of SO_2 and PM10 by 10%, NO_2 by 7%, and PM2.5 by 5% (guiding targets).
    - Three key regions were to reduce PM2.5 by 6% (binding target).

Table 2.2 China ambient air pollution targets in key regions, 2011-2015

	PM_{10}	SO_2	NO_2	$PM_{2.5}$
Ambient air concentration targets	10%	10%	7%	5% guiding (6% binding for 3 key regions)
Emission reduction targets	----	12%	13%	10% from industrial sources

Cities failing to meet the targets need to publically publish attainment plans for how to merge the gap in air quality. Forty-seven cities were required to meet even stricter emission standards and targets with new projects were required to offset twice their emissions.

Additional policy measures include:

- adjusting industrial structure;
- shutting down high polluting enterprises;
- promoting clean energy including renewable energy and natural gas;
- piloting a regional coal consumption cap in 3 key regions and the Shandong city cluster;
- expanding coal-free zones;
- phasing out small industrial coal boilers;
- reducing rural indoor coal burning;
- improving coal quality;
- upgrading vehicle emission and fuel standards; and
- other energy efficiency measures.

Given ongoing rapid rates of economic and industrial growth, emissions are unlikely to be reduced for at least another decade as constraints on industrial pollution continue to tighten through to 2020. Nationally, during the 12th FYP, GDP is forecast to increase 50%, coal consumption by 30% and motor vehicles by 50%. All of these factors will make it increasingly difficult to curtail the growth in pollutants.

The Action Plan of September 2013

Existing air pollution measures have been acknowledged as failing to tackle the regional and the transboundary nature of air pollution, especially in the Beijing-Tianjin-Hebei region where it is estimated that 30-40% of SO_2 emissions are sourced outside each region. Figures for NO_x and PM10 are estimated at around 12-20% and 16-26%, respectively.

International precedents for tackling air pollution on a regional scale include the 1979 Convention on Long-range Transboundary Air Pollution, 1985 Helsinki Protocol on the reduction of sulphur emissions and Sophia Protocol on the control of emissions of nitrogen oxides.

In China, the response has typically focussed on cities and includes the following:

- The Law of the People's Republic of China on the Prevention and Control of Air Pollution
- National Ambient Air Quality Standards
- *12th Five Year Plan on Air Pollution Prevention and Control for the Key Regions* (September 2012)
    - Investment cost: US$275 billion investment program for combating air pollution

- State Council Air Pollution Action Plan for 3 Key Regions to 2017 (September 2013) 国务院关于印发大气污染防治行动计划的通知 http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm
    - No new coal power plants in key regions (first time such a ban is imposed)
    - 2012 estimate of further 557 GW of coal power capacity in the pipeline (http://www.wri.org/publication/global-coal-risk-assessment) 15/363 projects located in key regions – yet 80% of proposed projects are exempt from ban and new AQ standards.
- Beijing Clean Air Action Plan (2013-2017) (September 2013)《北京市2013-2017年清洁空气行动计划》
- Hebei Implementation Scheme of Action Plan of Air Pollution Prevention and Control (September 2013) 河北省《大气污染防治行动计划实施方案》
    - Limits on industrial pollution including key polluting sectors of iron, cement, electricity and glass (contribute 60% of Hebei's SO_2 and 53% of coal use – 167 mt)
    - Reduce production of:
        - iron and steel by 60 million tons and 40 million tons of coal consumption by 2017 (compare this with 3 key region target of 15 million tonnes of iron and steel production by 2015)
        - 61 million tons of cement capacity will be closed
        - 1.8 million tonnes of glass by 2018.
    - Spending RMB 291 million to establish real time comprehensive AQ monitoring network
- China, South Korea and Japan Regional Agreement on Air Pollution (December 2013)

Regional cooperation was trialled and generally successfully implemented in the short term during the 2008 Beijing Olympics, the 2010 Shanghai Expo and the 2010 Guangzhou Asian Games. The three key regions were affected by these events and resulted in the signing of regional air quality agreements covering SO_2, NOx, PM_{10} and VOCs.

The central element among these plans was the five year (2013-2017) road map and the Action Plan for reducing air pollution in the three key regions: Beijing-Tianjin-Hebei; Yangzi River Delta; and the Pearl River Delta. The Plan includes targeted reductions in emissions of fine particulates with the aim to substantially reduce the pollution of the three regions as follows:

- Mandatory targeted reduction in annual average concentrations of PM2.5 (based upon unpublished 2012 figures):
    - Beijing 25% reduction (60 μg/m^3 PM2.5 target set for Beijing, as well as 6 million motor vehicles cap)
    - Yangzi Delta Region 20% reduction
    - Pearl River Delta 15% reduction
    - 10% reduction for PM2.5 and PM10 in other key cities.
- Allocation of RMB 1.7 trillion to be invested over five years in tackling air pollution combined with limits on access to credit for polluting or non-compliant industries.
- Proportion of coal in total energy consumption to be reduced to 65%.

- Non-fossil energy resources to increase to 13% by 2017 (pre-existing target for 2020 was 15% but included nuclear).
- Key task 13 (of 35) – Adjust the energy structure:
  Natural gas to gradually replace coal in three key regions by 2017 in power stations, industrial furnaces and thermal heating plants. Gas power plants to supply peaking power. Gas supplies in the 3 key regions will be provided by an additional 150 bcm of transmission pipelines (unclear in Plan if this covers existing proposals which is most likely). Coal to gas expansion needs to ensure strict enforcement of environmental controls and the protection of water resources tightly monitored. Continue reforms to the energy pricing of natural gas to ensure a rationale pricing system is established in line with other energy sources.
- Most polluting heavy vehicles (yellow labelled) to be removed from 3 key regions by 2015 and nationally by 2017.
- Euro V equivalent fuel standards (petrol and diesel) to be introduced in 3 key regions in 2015 and nationally by 2017.
- Increased mechanisms for provincial and ministerial cooperation on air pollution (recently evidenced by Beijing-Tianjin-Hebei agreement with Shandong).
- Naming and shaming 10 worst and 10 best AQ cities on a monthly basis.

The 35 measures had already been announced previously but monitoring, implementation and enforcement measures were tightened in the September 2013 announcement. For instance, it emphasised the need to shut down backward and polluting industries as identified in the 12th FYP for Air Quality released in 2012. However, the 2013 Plan also reduced some of the earlier targets. For example, in 2012, China released the National Ambient Air Quality Standard (GB3095-2012) which required all cities should meet average annual PM2.5 levels of 35 μg/m^3 by 2016. On the one hand, the new targets are therefore not as stringent even for Beijing, but the difference is that the new targets are mandatory with penalties for cities and leading officials for failure to comply.

PAPER 3
A Case Study of Natural Gas in Guangdong

The Pearl River Delta is an especially dynamic and important region of China centered around the delta of the Pearl River and its tributaries and distributaries, notably the Xi Jiang, Bei Jiang and Dong Jiang rivers. It is normally taken to include nine prefectures within the province of Guangdong, including Guangzhou, Shenzhen and many other cities and extending into Hong Kong and Macau. The Delta region contains about 120 million people, is a major global manufacturing and distribution centre and a key destination for foreign investment, and has experienced sustained rapid growth.

The Delta region is heavily polluted, but its air quality has generally been better than many other regions in China. Nevertheless, as noted above, the State Council designated the Pearl River Delta area as one of the three priority areas in the September 2013 Action Plan to address air quality. This case study provides a background to the role of natural gas in the energy structure of Guangdong, focusing on the following three issues: the nature and structure of the rapid growth in natural gas consumption in the province; the future outlook for natural gas in Guangdong prior to the launch of the Action Plan, which was already very strong; and the issues surrounding the pricing of natural gas in the province. The latter is especially relevant given that Guangdong has been often used by the central government as a venue for pilot programs in relation to gas pricing.

Although Guangdong (or at least the Pearl River Delta) was designated as a priority area in the Action Plan, a detailed follow-up plan has not yet been published. It has been reported in the China Daily that the provincial government approved the province's action plan on 31 December 2013, and that it would target lowers levels of air pollution in key cities than mandated under the national plan (China Daily, 4 January 2013). But the plan has not yet been published and details are not yet available.

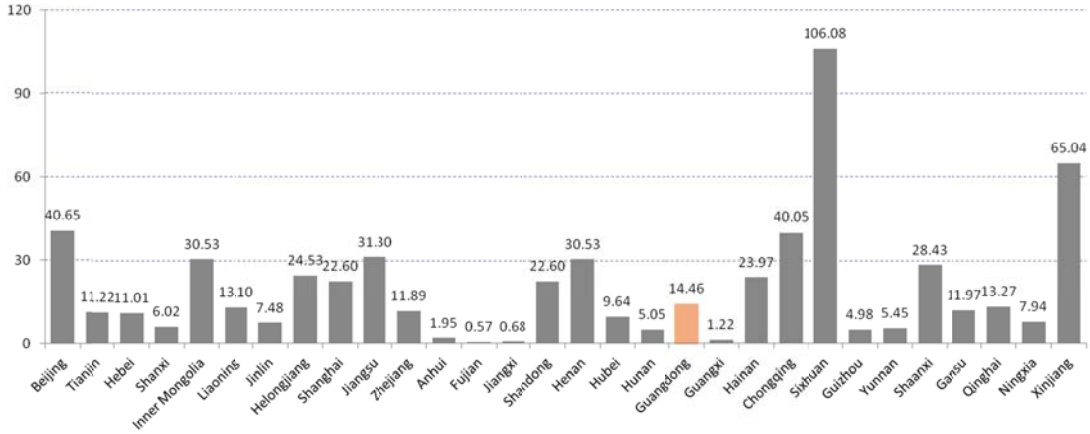
Rapid Growth in Demand

Guangdong's position in national natural gas consumption

Gas consumption in Guangdong has been accelerating since 2006. It ranked 6th at the national level in gas consumption in 2005, and jumped to top five in 2006, due mainly to LNG imports from Australia in the second half of 2006, which boosted both primary and final consumption in the province. Ever since, Guangdong has retained its top 5th position in natural gas consumption. In 2011, according to China National Statistics Bureau data, it became the second largest gas consuming province in China, accounted for 9% of national total (see figures 3.1 and 3.2).

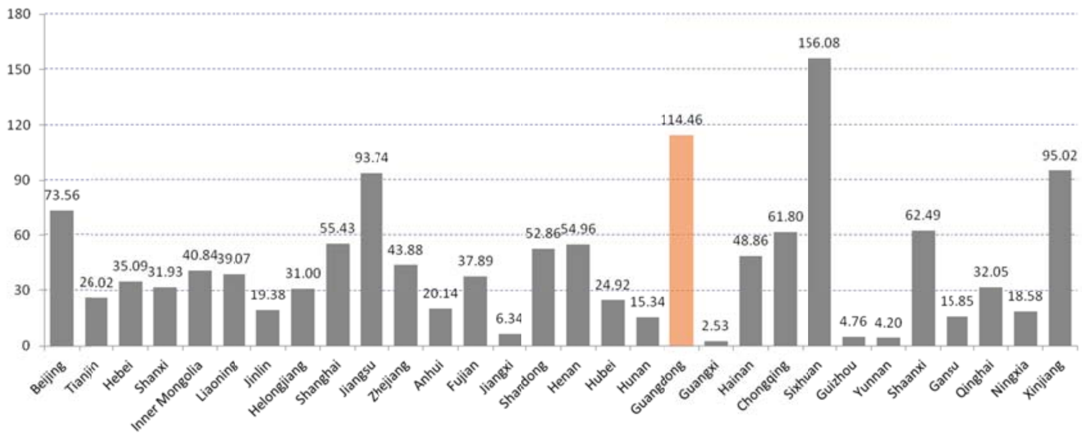
Apart from the two gas producing provinces of Sichuan and Xinjiang, consumption in Guangdong was the highest in the nation in 2011, reaching 11.4 bcm in that year, an eightfold increase on the figure for 2005. After Guangdong, the largest usage was in Jiangsu (9.4 bcm) and Beijing (7.4 bcm).

Figure 3.1 China natural gas consumption by region, 2006, 100 million cm



Source: Wind.

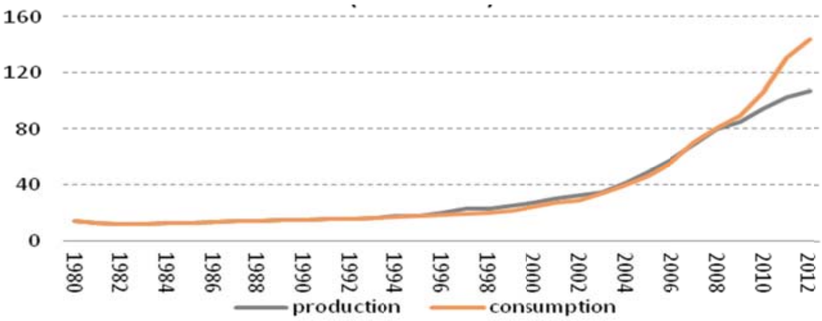
Figure 3.2 China natural gas consumption by region, 2011, 100 million cm



Source: Wind.

China's natural gas production has been growing steadily since the mid 1990s (see Figure 3.3), and broadly matched the pace of consumption expansion until 2007. The arrival of significant imports of natural gas in 2007 allowed consumption to surpass domestic production. The gap between production and consumption has been met by imports from overseas.

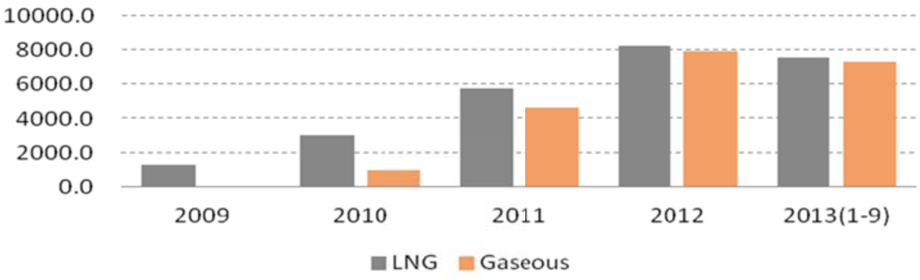
Figure 3.3 China natural gas production and consumption volume, billion cm



Source: Wind.

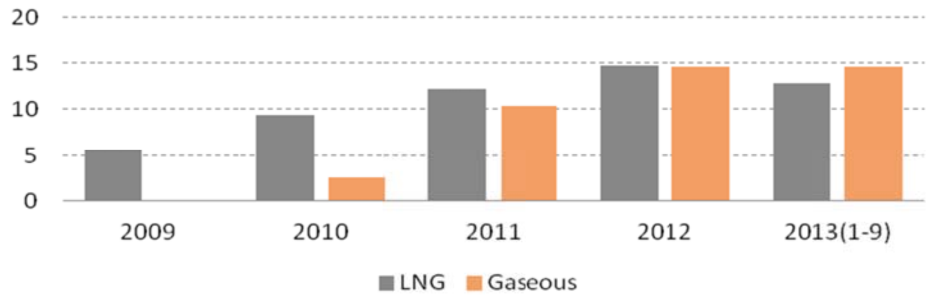
Figures 3.4 and 3.5 show the expansion of China's gas imports from overseas, in terms of both value and volume. These imports take two forms – gaseous imports by pipeline, from countries such as Qatar and Turkmenistan, and imports of gas in liquefied form (LNG) from countries such as Australia. In 2012, China spent about US$16 billion on natural gas imports, about equally divided between the two forms of gas, by comparison with less than US$2 billion in 2009.

Figure 3.4 China LNG and gaseous natural gas imports, million USD



Source: Wind.

Figure 3.5 China LNG and gaseous natural imports, million tons



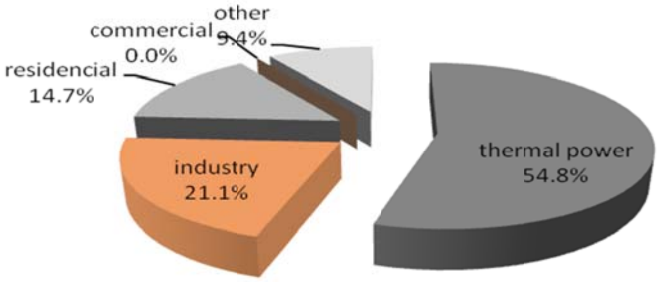
Source: Wind.

Guangdong is a resource poor region in China. Its natural gas provision comes from three major sources. One is contracted import LNG from Australia, a supply of 3.7 million tons or about 5 bms per year. The second source is the West-East natural gas 2nd pipeline conveying Turkmenistan gas to Guangdong. It was reported that starting from November 2011, this pipeline gas was to transport 10 bcms of natural gas each year to Guangdong, of which 40% was for Shenzhen and 60% was for the rest of Guangdong. The third source is offshore oil associated gas in the South China Sea, which is being developed by the China National Offshore Oil Corporation. With the current structure, the import of Australian LNG accounted for about 43% of 2011 Guangdong natural gas consumption. To meet with growing demand in natural gas, and being a gas resource poor region, the Guangdong government has been putting a great effort in expanding its gas supply sources as well as its receiving capacity, which will be touched upon later.

Consumption structure: Thermal power generation accounted for a major part

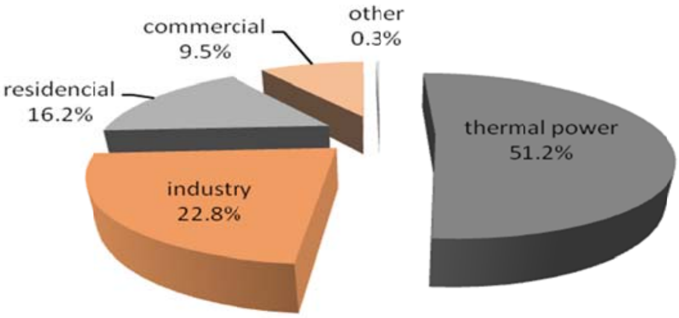
An important characteristic of Guangdong in terms of gas use is that power generation has accounted for over half of its total gas use.. As shown in figures 3.6 and 3.7, in five years, the share of different sectors in Guangdong's total natural gas consumption has changed with thermal power generation accounting for less, while all others have increased their shares.

Figure 3.6 Components as a share of Guangdong natural gas consumption, 2006, %



Source: CEIC.

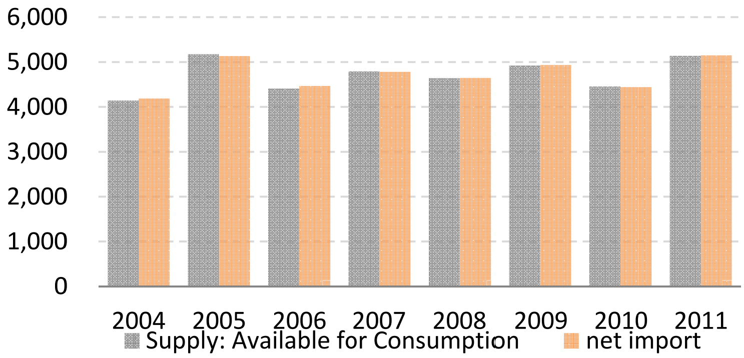
Figure 3.7 Components as a share of Guangdong natural gas consumption, 2011, %



Source: CEIC.

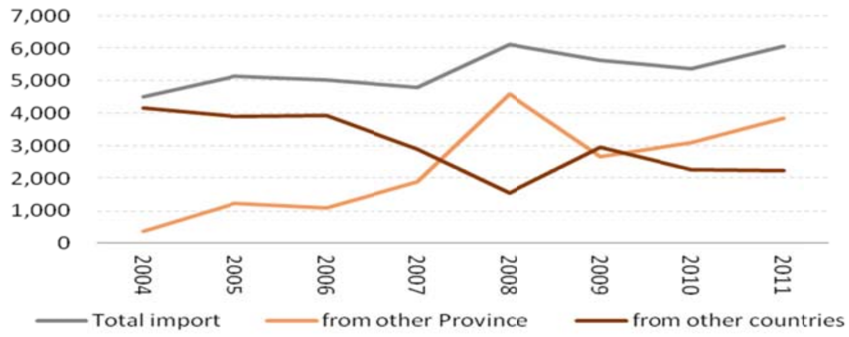
Guangdong's LPG consumption has been fully dependent on imports from both domestic and international sources. Of the total, over 60% was from other provinces in 2011, and less than 40% from imports overseas. Its LPG consumption has been relatively stable in the past few years in contrast with rapid increases in other forms of gas consumption. Residential consumption accounted for a large part of final LPG consumption in Guangdong (Figure 3.10).

Figure 3.8 LPG supply, consumption and imports in Guangdong, thousand tons



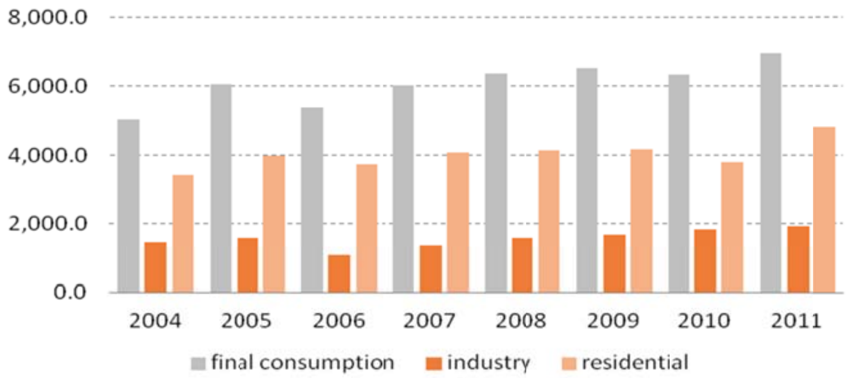
Source: CEIC.

Figure 3.9 Guangdong LPG imports, thousand tons



Source: CEIC.

Figure 3.10 Guangdong LPG final consumption, thousand tons



Source: CEIC.

Projections for Natural Gas Consumption in Guangdong before the Action Plan

Official consumption projection: local and national

In the *12th Five-year Plan for Guangdong Energy Development*, to achieve its goal of increasing clean energy usage in total energy consumption from 27.8% in 2010 to 39.4% in 2015, it was planned that Guangdong's share of natural gas to total energy consumption would increase from 8.6% in 2010 to 13.2% by 2015. The supply of natural gas is projected to rise from 9 bcms per annum in the 11th five-year plan period to 43 bcm per annum (GDDPC 2012). According to *Guangdong Oil and Gas Backbone Network Plan* (2009), by 2020, the total natural gas supply in Guangdong Province will be at about 60 bcm per year, the total length of pipelines in the province will be 4000 km, with a total investment of about RMB 54 billion.

Table 3.1 Composition of primary energy consumption in Guangdong, as % in total

	Coal	Oil	Gas	Other*
2005	42.9	33.8	5.7	17.6
2010	42.4	30.0	8.6	19.2
2015 (planned)	36.2	24.2	13.2	26.2

Note: * Including electricity transmitted from Yunnan and Guizhou, hydro power, nuclear power, wind power, solar and bio energy.
Source: GDDRC (2012).

Table 3.2 An official projection of total energy demand in Guangdong

	2005	2010	2015*
Primary energy consumption (mil sce)	179.2	271.95	327.4-358.8
Coal (mil tons)	102.2	159.8	166-177.3
Oil (mil tons)	44.4	55.6	56-57.3
Gas (mil sce)	11.3	23.5	42.8-61.3
Natural gas (100 mil cms)	2.5	95.0	300-430
LPG (mil tons)	5.2	5.6	2.5-3.5
Other (mil sce)	26.6	52.0	86.0
Per capita energy consumption(ton sce/person) residents)	1.93	2.66	3.16-3.47
Power consumption (bil kwh)	267.4	406.0	630.0
Coal power generation in total coal consumption (%)	66.2	67.2	73-78

Note: * 2015 estimations were made according to the goals of economic development and energy consumption control in the *12th Five-year Plan for Social and Economic Development in Guangdong Province* (GDDPC, 2012).
Source: GDDPC (2012).

According to Han and Yang (2012), assuming an annual growth rate of 3% for urban population in the 12th five-year plan period, same as that from 2000 to 2010, urban gas consumption would amount to 67.7 bm by 2015, tripling the 2010 level of 22.5 bcm. The national gas consumption is projected to reach 229 bcm by 2015, nearly double the 2011 figure of 126.8 bcm, with an annual growth rate of 18.5% (Han and Yang 2012). If Guangdong's natural gas provision reaches 43 bms in 2015 based on the figure from the Guangdong Development and Reform Commission's plan for energy development in the twelfth five-year plan period, the share of Guangdong to China's natural gas consumption would be around 19%.

Plans to boost infrastructure construction to meet with growing demand

According to the *Twelfth Five-year Plan for Natural Gas Development* issued by NDRC and the National Energy Administration, it is planned to construct new pipelines (including sub-lines) 44,000 km long with a transmission capacity of 150 bcm per year, new natural gas storage with a working gas volume of 22 bcm, which would account for 9% of the total yearly consumption. This is in comparison to 2010 which had a backbone pipeline length of 40,000 kms, a working gas volume of underground storage of 1.8 billion cms, and 3 established LNG reception station with capacity of 12.3 million tons per year (NDRC 2012).

It was expected that, by 2015, China's contracted LNG import would come to 93.5 bcm.

Table 3.3 China's LNG reception stations, in operation and under construction

Name of project	Location	Affiliation	Designed capacity (mil tons/yr)		Time start operation
			Stage 1	*Stage 2*	
Guangdong Dapeng	Dapeng Bay, Shenzhen, Guangdong	CNOOC	3.7	6.7	2006
Fujian Putian	Meizhou Bay, Putian, Fujian	CNOOC	2.6	6	2008
Shanghai Yangshan	Yangshan Deepwater Port, Shanghai	CNOOC	3	6	2009
Jiangsu Rudong	Rudong Yangkou Port, Jiangsu	PetroChina	3.5	6.5	2011
Liaoning Dalian	Dagushan, Dalian, Liaoning	PetroChina	3	6	2011
Zhejiang Ningbo	Zhongzhai, Baifeng Town, Ningbo, Zhejiang	CNOOC	3	9	2012
Zhuhai Jinwan	Gaolan Port, Zhuhai, Guangdong	CNOOC	3.5	7	2012
Shandong Qingdao	Dongjiakou, Jiaonan, Qingdao, Shandong	Sinopec	3	6	2013
Yuedong Jieyang	Huilai County, Jieyang, Guangdong	CNOOC	2	4	2013
Hebei Caofeidian	Caofeidian Harbour District, Tangshan, Hebei	PetroChina	3.5	6.5	2013
Hainan LNG	Yangpu Economic Development Zone, Hainan	CNOOC	2	3	2014

Source: Han and Yang (2012, p. 61).

By the end of 2010, the length of Guangdong natural gas pipelines was about 900 km. It connected major cities in Guangdong, i.e. Guangzhou, Shenzhen, Foshan, Dongguan and Zhongshan. In the twelfth five-year plan period, forming a comprehensive backbone natural gas network is one of the major tasks for Guangdong's energy development. It is the integral part of the three energy supply networks, namely the power grid, natural gas pipelines and petroleum transmission backbone pipelines (GDDPC 2012).

Table 3.4 Contracted LNG supply, 2006-2015, as at 2012, million tons/year

	2006	2007	2008	2009	2010	2011	2012e	2013e	2014e	2015e
Australia–NSW	2	3.25	2.72	3.5	3.9	3.64	3.25	3.25	3.25	3.25
Indonesia–Tangguh	0.54	1.71	2	2.6	2.6	2.6	2.6			
Malaysia–Petronas	0.66	1.2	1.6	3	3	3	3			
QatarGas, Stage 2	0.4	1.2	1.5	2	2	2	2			
QatarGas, Stage 4			0.8	1.8	3	3	3			
QatarGas, Stage 3					1.5	3	3			
GDF-Suez								1.3	2.6	2.6
Sum									0.5	1
Australia									1	2.28
Australia									0.5	1
Papua New Guinea									0.54	1.53
Australia										0.5
APLNG										1.44
Other-spot supply			0.61	0.44	1.33	2.62	1.33	1.7	2.2	2.7
Total supply	**2**	**3.25**	**3.33**	**5.54**	**9.34**	**12.16**	**13.98**	**18.35**	**24.19**	**29.9**

Source: Han and Yang (2012, p. 61).

According to the *12th Five-year Plan for Guangdong Energy Development*, tasks that relate to local natural gas development in the planning period are:

1. To reasonably allocate and establish natural gas power generation and distributed power generation facilities in the Pearl River Delta region, with newly installed gas power generation capacity of about 7.1 million kilowatts (of which, 6.3 million kilowatts are co-generation units and small distributed power generation stations).
2. To complete the construction of LNG and offshore natural gas receiving stations in Shenzhen, Zhuhai, Jieyang in East Guangdong, Zhanjiang in West Guangdong, to establish a new supply capacity of 34 bcm per year.
3. To form an integrated natural gas backbone network, which radiates from the Pearl River Delta, connecting all types of gas sources (including LNG reception points, land long-distance pipelines and offshore gas receptions), and all cities at and above the prefectural level, with a total length of backbone network to increase to 3300 km by 2015.
4. To build natural gas reserve and emergency reaction facilities in the large and medium-sized cities, and to construct gas provision pipelines to Hong Kong and Macau.

It is expected that the total expense of the 10 projects planned for investment in LNG reception stations and gas transport pipelines would amount to RMB 84.5 billion in the 12th Five-year Plan period, accounting for 10% of all energy-related investment of the province for that period (GDDRC 2012).

In 2010, Guangdong SDRC announced its 'Infrastructure Integration Construction Plan for the Pearl River Delta Region (2009-2020)' (GDDPC 2010). The region covers the more developed areas in Guangdong, including Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, Huizhou and Zhaoqing cities, in conjunction with east, west and north of Guangdong and Hong Kong and Macau. In this plan, in relation to natural gas development, the goal to achieve by 2020, is a 'one net' – an integrated natural gas backbone network which connects various natural gas supply sources. Between 2012 and 2020, the north backbone pipeline is to connect with Shenzhen Dapeng LNG, East Guangdong LNG, West Guangdong and Zhuhai LNG stations. By 2012, the natural gas pipeline was 1700kms, and would be extended to 4300kms by 2020.

Until then, there will be a West-East pipeline, a Sichuan-East natural gas transmission line, a Shenzhen Dapeng LNG, four other LNG receiving points, and two offshore oil associated gas fields, to form a more comprehensive natural gas supply system to meet with fast growing demand in natural gas consumption in Guangdong.

Table 3.5 Guangdong LNG reception and pipeline facilities, current and future

	Status
LNG import reception facilities	
Dapeng, Shenzhen	In operation
Jiufeng, Dongguan	In operation
Jieyang by CNOOC	Under construction
Zhuhai by CNOOC	Under construction
Shezhen by CNOOC	Under construction
Zhanjiang by CNOOC	Planned
Maoming by Sinopec	Planned
Shenzhen by PetroChina	Planned
Sailuo, Shantou	Planned
Onshore natural gas projects	
West-East natural gas transmission, 2nd line	Under construction
West-East natural gas transmission, 3rd line	Planned
West-East natural gas transmission, 4th line	Planned
Sichuan-East natural gas transmission	Under construction
Offshore natural gas projects	
Panyu Gas Field, Huizhou	In operation
Liwan Gas Field	Under construction
Total number of projects	**Number**
In operation	3
Under construction	6
Planned	6

Notes: CNOOC (China National Offshore Oil Corporation); Sinopec (China Petroleum and Chemical Corporation); PetroChina (China National Petroleum Corporation).
Source: Deng 2012.

China's Gas Price Reforms and the Pilot in Guangdong

The final user prices of natural gas in China consist of the following three parts: the wellhead price, the transportation and transmission tariff and the city distribution cost plus margin. The wellhead price, which reflects the costs of natural gas exploitation, infrastructural building and gas production, is the same as the plant gate price of natural gas. The transportation and transmission tariff reflects the costs for pipeline construction and operation. The wellhead price and the transportation and transmission tariff make up city gate price. The city distribution cost plus margin are the costs of the sub-lines and construction of related facilities and operational costs after the natural gas is transmitted to a city (Wang 2011).

The history of China's gas price reforms

The processes of China's market oriented reforms for gas prices can be divided into three major stages: Stage I (1958-92), Stage II (1992-2005) and Stage III (post 2005 period). Prior to 1993, China's natural gas price was set by the government. Even after 1982 when a single gas price was replaced by a dual price system (with quota and over quota prices), both the quota and over quota prices were set by the state.

In Stage I, gas producers were required to sell all their gas to state designated buyers. Stage I of the price reform can be divided further into two periods: the period from 1958 to 1981 and the period from 1982-1992. The former period was characterized by low-planned gas prices for encouraging gas consumption in production areas, due to the limited amount of gas produced and the poor facilities for gas transportation. In 1958, the government slashed gas price from RMB 70 to RMB 30 per thousand cubic meters. In the latter period, in an effort to raise funds for gas exploitation, the government increased gas prices by introducing a higher price for gas produced over quota.

In Stage II, the planned price co-existed with the state guidance prices for gas. In 1993, gas producers were allowed to sell part of their gas on the market.[3] In 1994, the dual prices for gas were removed and replaced by a single state set price. At the same time, a benchmark price (guidance price) was introduced by the state for gas sold on the market and gas producers were allowed to float their prices by 10% around the benchmark price for their produce sold on the market. The introduction of the guidance price for the gas sold on the market had increased revenues of the gas producers for gas exploitation and raised gas output. In 2002, a price adjustment mechanism was adopted where the natural gas plant gate price was linked to the changes in the prices of crude oil, LPG and coal.

At the end of 2005 in Stage III, the Chinese government introduced the cost plus pricing model by setting the gas prices based on the sources and uses of gas. Under the model, firstly, different guidance prices were set for gas used for producing fertilizers, for direct industrial use and for urban consumption, with lower prices of gas for fertilizer production and urban consumption. Secondly, the producers from China's major oil fields were allowed to float their guidance prices upward and downward by up to 10%, whilst the gas producers from other domestic sources were allowed to float their guidance prices upward by 10%, with no restrictions on downward floating (Zhang 2013).

The introduction of the cost-plus pricing model introduced in 2005 caused a great deal of confusion, with different prices applied to the same product coming from different sources and used for different purposes. It also happened that the final user price became even lower than the border price for certain imported LNG, which led to heavy financial losses for gas importing firms. Furthermore, the lower retail prices for domestically produced natural gas created a shortage in gas supply.

[3] Prior to 1993, gas producers sold all their gas to state designated buyers.

Table 3.6 Plant gate baseline prices for domestically produced natural gas, 2010, yuan/th cms

	By gas uses			
Sources of gas	Fertilizer	Large industry users	Urban use: Industry	Urban use : Non-industry
Chuanyu gas field	920	1505	1550	1150
Changqing oil field	940	1355	1400	1000
Qinghai oil field	890	1290	1290	890
Oil fields in Xinjiang	790	1215	1190	790
Dagang, Liaohe & Zhongyuan oil fields	940	1570	1570	1170
Other oil fields	1210	1610	1610	1210
West-East pipeline	790	1190	1190	790
Zhongwu Pipeline	1141	1541	1541	1141
Shaanxi-Beijing pipeline	1060	1460	1460	1060
Sichuan-East pipeline	1510			

Source: NDRC 2010.

Table 3.7 West-east Stage 1 pipeline gas prices, enacted in 2003, yuan/cubic meter

	Producer price	Transmission price	Average city gate price	End user price	Price for using in fertilizer production	Price for using in power generation
Henan	0.48	0.66	1.14	1.14	1.12	/
Anhui	0.48	0.75	1.23	1.23	/	/
Jiangsu	0.48	0.79	1.27	1.27	1.27	1.10
Zhejiang	0.48	0.83	1.31	1.31	/	1.20
Shanghai	0.48	0.84	1.32	1.32	1.28	1.15

Source: Wang 2011.

Pilot price reform in Guangdong Province

At the end of 2011, a pilot 'net-back pricing model' program was introduced in Guangdong and Guangxi to reform the prices of natural gas further. On 27 November 2011, China's NDRC released 'An Announcement for Conducting Pilot Reforms on the Formation of Natural Gas Prices in Guangdong Province and Guangxi Autonomous Region'. Guangdong's natural gas market emerged in 2006 when the province started to import LNG from Australia. Since then, Guangdong has also imported gas from Sichuan and Shaanxi provinces through the west-east pipeline Stage 2, Stage 3 and from China's offshore production. Guangdong was regarded as a good place for a pilot gas price reform, as the province has a relatively new gas market and bulk of its supply has been from overseas at higher prices (Xinhua News 2011).

The purpose of this pilot net-back pricing model, according to NDRC, is to reduce the price disparities between natural gas and alternative energy sources so as to achieve a more rational allocation of natural gas resources and to promote economical use of natural gas. The net-back pricing model takes Shanghai as the benchmark market, giving 60% and 40% weight to the prices of imported fuel oil and LPG, respectively, as alternative energy price reference, and multiplying by 0.9 to form the Shanghai hub price for natural gas. The city gate prices in Guangdong and Guangxi are obtained by adding the transportation and transmission tariff to the Shanghai hub price, modified by a coefficient related to the income levels in the two provinces (NDRC 2011). Under the new model, the city gate price in the pilot regions will be adjusted regularly, depending on the changes in alternative energy prices. At the same time, price control over wellhead prices for non-conventional natural gases, such as shale gas, coal seam gas and coal gas was removed. A unified city gate price would be applied to gases from various sources being transmitted through pipelines. The net-back pricing is more market oriented, as the previously state set wellhead price for natural gas is replaced with a Shanghai hub price, which is determined mainly on the imported prices of fuel oil and LPG. The gas prices in the two pilot provinces are, however, projected to rise under the net-back pricing model, with more pipeline gas supplies.

According to the net-back pricing method based on the 2010 fuel oil and LPG import prices (corresponding crude oil price was about US$80 per barrel), the NDRC confirmed Guangdong's city gate price of RMB 2.74 per cubic meter (Guangxi's city gate price was set at RMB 2.57 per cubic meter). The new city gate prices calculated under the net-back pricing model at RMB 2.74 and RMB 2.57 per cm were lower than the prices of gas in the province except the price of imported Australian LNG. Therefore, the new prices introduced have had a limited effect on gas users (Xinhua News 2011).

Replication of the Guangdong pilot in China

The Chinese Government launched a new nation-wide reform for gas prices in 2013 based on the lessons drawn from the pilot price reform in Guangdong and Giuangxi. The ultimate goal of the natural gas price reform is to let the market determine the wellhead gas price (Xinhua News 2013). The government divided the domestic gas supply into two parts: the gas supply at 2013 production level (cun-liang gas) and the incremental gas supply (zeng-liang gas), i.e. any gas supply over the production level in 2013. From 10 July 2013, the net-back pricing model piloted in Guangdong and Guangxi was applied to all the incremental gas supply (zeng-liang gas) and prices of cun-liang gas were raised as well. Following the reform, the prices of zeng-liang gas rose to the level at around 85% of the prices for alternative sources of energy (fuel oil and LPG) and the use based price disparity for zeng-liang gas was removed. The prices for cun-liang gas were to rise at no more than RMB 0.4 per cubic meter. The impact of the gas price hike has been limited as cun-liang gas still accounted for 91% of natural gas consumption in China (112 bcm). Following the reform, the city gate gas price on average increased from RMB 1.69 to RMB 1.95 per cubic meter (NDRC 2013).

As shown in Table 3.8, apart from the prices in Guangdong and Guangxi where the net-back pricing model has been applied, the new city gate prices for zeng-liang gas in all the other provinces have been much higher than their cun-liang gas prices in the extent of 35-60%. Apparently, the price reform in combination with a fast-rising demand has led to an upward movement in China's natural gas prices.

Table 3.8 Pipeline gas city gate price ceilings for stock consumption and incremental consumption by province, yuan/cms

	Stock	Incremental	Difference %		Stock	Incremental	Difference %
Beijing	2.26	3.14	38.90	Hubei	2.22	3.10	39.60
Tianjin	2.26	3.14	38.90	Hunan	2.22	3.10	39.60
Hebei	2.24	3.12	39.30	Guangdong	2.74	3.32	21.20
Shanxi	2.17	3.05	40.60	Guangxi	2.57	3.15	22.60
Inner Mongolia	1.60	2.48	55.00	Hainan	1.92	2.78	44.80
Liaoning	2.24	3.12	39.30	Chongqing	1.92	2.78	44.80
Jilin	2.02	2.90	43.60	Sichuan	1.93	2.79	44.60
Heilongjiang	2.02	2.90	43.60	Guizhou	1.97	2.85	44.70
Shanghai	2.44	3.32	36.10	Yunnan	1.97	2.85	44.70
Jiangsu	2.42	3.30	36.40	Shaanxi	1.60	2.48	55.00
Zhejiang	2.43	3.31	36.20	Gansu	1.69	2.57	52.10
Anhui	2.35	3.23	37.40	Ningxia	1.77	2.65	49.70
Jiangxi	2.22	3.10	39.60	Qinghai	1.53	2.41	57.50
Shandong	2.24	3.12	39.30	Xinjiang	1.41	2.29	62.40
Henan	2.27	3.15	38.80				

Source: NDRC 2013, http://www.ndrc.zcfb/zcfbtz/w020130628590647781363.pdf

PAPER 4
A Case Study of Natural Gas in Beijing

Introduction

China's 12th five-year gas plan projects a rapid increase in gas consumption by 2015, due mainly to the continuous process of urbanization and substitution of gas as a clean energy source for other types of energy. The government has become increasingly concerned with gas security, as the ratio of imports to total gas consumption in China are estimated to rise from 15% in 2010 to 35% in 2015. As China's political, scientific and cultural center, Beijing is a frontline city for the increased use of gas in China, given the rapidly rising demand for energy, deteriorating air quality and relatively abundant fiscal resources of the megacity. This case study has important implication for other Chinese megacities with similar income levels, such as Shanghai, Tianjin, Guangzhou and other eastern provincial capital cities.

Rapid Increase in Gas Consumption for Non-industrial Uses in Beijing

Beijing has witnessed rapid growth in its gas consumption. From 1995 to 2011, Beijing achieved a higher rate of growth in gas consumption compared with the rest of China (see Table 4.1 and Figure 4.1). The megacity achieved double-digit growth in gas consumption in 13 of the 16 years (1995-2001). Accordingly, Beijing's share of gas consumption compared to all of China surged from 0.7% in 1995 to 5.6% in 2011. The growth in Beijing's gas consumption has however been volatile: the growth rate fluctuated from a minimum of -1.6% in 2011 to a maximum of 106% in 1998. The gap of the growth rate between Beijing and all China widened significantly from 1998 to 2001 and narrowed thereafter. According to a recent report, Beijing's gas consumption has trended up after 2011 (China Economic Times, 25 Nov 2013).

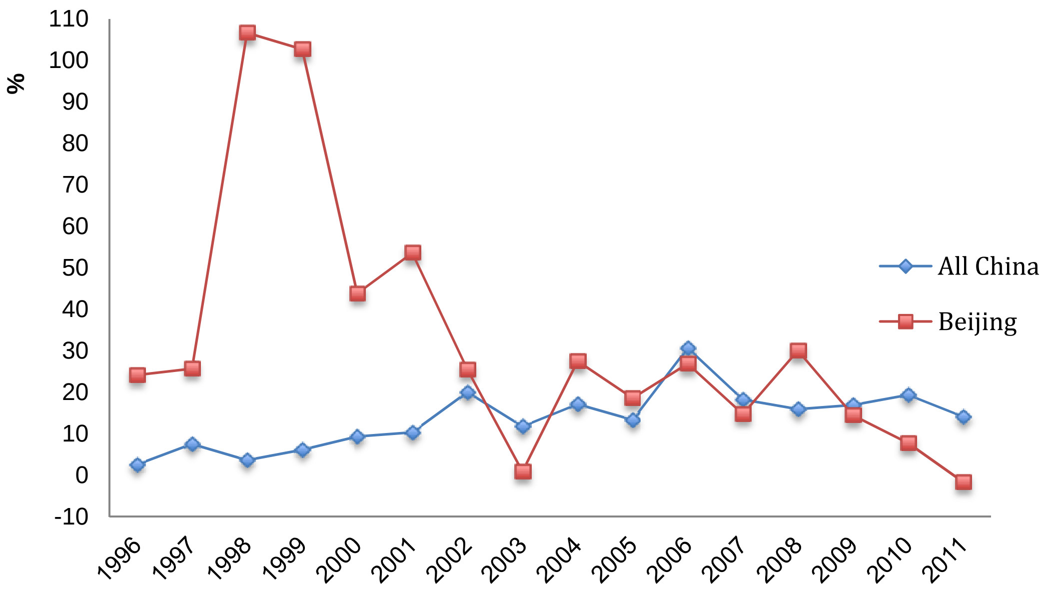
Table 4.1 Annual growth in gas consumption in Beijing and all China, 1998-2011

	China cub m, mn[1]	Growth[2] %	Beijing cub m, mn	Growth[2] %	Share[3] %
1998	20,277	3.6	374	106.6	1.8
1999	21,519	6.1	758	102.7	3.5
2000	23,531	9.3	1,090	43.8	4.6
2001	25,963	10.3	1,674	53.6	6.4
2002	31,160	20.0	2,100	25.4	6.7
2003	34,829	11.8	2,119	0.9	6.1
2004	40,798	17.1	2,702	27.5	6.6
2005	46,241	13.3	3,204	18.6	6.9
2006	60,422	30.7	4,065	26.9	6.7
2007	71,442	18.2	4,664	14.7	6.5
2008	82,833	15.9	6,065	30.0	7.3
2009	96,844	16.9	6,940	14.4	7.2
2010	115,610	19.4	7,479	7.8	6.5
2011	131,907	14.1	7,356	(1.6)	5.6

Notes: 1. Unit: million cubic meters. 2. Annual rate of growth over the previous year. 3. The share of gas consumption in Beijing to all China.

Source: NSB 2012, *China Energy Statistical Yearbook 2012*.

Figure 4.1 Annual growth of gas consumption, Beijing and all China, 1996-2011



Beijing's share of gas consumption compared to all Chinese cities exceeded 10%. Beijing accounted for between 10.6% and 16.9% of gas consumption in all the Chinese cities 2000-11 (Table 4.2).[4] Beijing's share of gas consumption in Chinese cities was higher than those in Shanghai and Tianjin. Shanghai's share of gas consumption jumped from 3.2% in 2000 to over 8% in 2009-11, whilst Tianjin's share declined during the same period of time. The increase in Shanghai's gas consumption is even more remarkable considering Beijing and Tianjin are northern cities requiring more energy consumption in winter. A higher percentage of gas consumption for Beijing and Shanghai could be attributed, inter alia, to higher levels of incomes in the two megacities.

Table 4.2 Supply of natural gas, all Chinese cities, million cubic meters

	All China	Beijing	%[1]	Shanghai	%	Tianjin	%
2000	8,214.8	957.4	11.7	259.7	3.2	234.7	2.9
2005	21,049.5	3,174.0	15.1	1749.6	8.3	689.7	3.3
2009	40,510.0	6,828.4	16.9	3343.9	8.3	1497.4	3.7
2010	48,758.1	7,197.4	14.8	4500.3	9.2	1694.5	3.5
2011	67,880.0	7,296.1	10.7	5433.1	8.0	1697.4	2.5

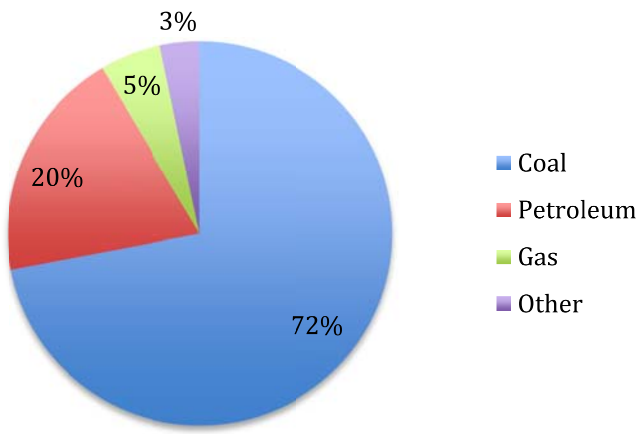
Notes: 1. % of All China.
Source: NSB 2012, *China Energy Statistical Yearbook 2012*.

Beijing has a higher ratio of gas in total energy consumption. Of China's total energy consumption in 2011 (calculated by calorific value), 72% came from coal, 19.5% from petroleum, 5.2% from gas, and the remaining 3.3% from hydro, nuclear power and other energy sources (Figure 4.2). By 2013,

[4] The cities here refer to the cities above the prefecture level. The townships at and below the county levels in China are defined as rural areas. Many China's industrial parks and resource bases are located in 'rural' areas.

gas constituted about 5.5% of energy consumption in China, which is far below the world average of 24%. However, reports suggest that the ratio of gas to total energy consumption in Beijing has reached 14% in 2012-2013, 9 percentage points (ppts) higher than the national average.[5]

Figure 4.2 Consumption of energy consumption, China, 2011, %



Beijing has used more gas for heating, cooling and other residential uses. The higher ratio of gas to total energy consumption in Beijing is related to gas uses. It appears that the most common uses of gas in Beijing are for heating, cooling and domestic fuels (Table 4.3). Compared with the rest of China, the share of thermal power and heating (mainly for cooling and heating) in Beijing's gas consumption was 20 ppts higher than that for the whole nation, and its share of manufacturing and transport uses in gas consumption was 30 ppts lower than the nation. Beijing's share of hot water supply capacity compared to all China increased from 4.9% in 2000 to 10.9% in 2011, an increase of 10 ppts in 10 years (Table 4.4).

Table 4.3 Uses of gas, Beijing and China, 2011

	National		Beijing	
	cub m bn[1]	%[2]	cub m mn[3]	%[2]
Total supply	130.5	100	7,296	100
Thermal power and heat supply	22.5	17.2	2,634	36.1
Primary industries	13.2	10.1	1	0.1
Manufacturing	48.3	37.0	853	11.7
Construction	0.1	0.1	41	0.6
Transport and storage	13.8	10.6	238	3.3
Other services[4]	3.4	2.6	450	6.2
Residential consumption	26.4	20.3	1,049	14.4
Other	2.8	2.1	2,030	27.8

Notes: 1. Unit: billion cubic meters. 2. % of the total supply. 3. Unit: million cubic meter. 4. Other services here refer to trade and commerce, hotels and restaurants.
Source: NSB 2012, *China Energy Statistical Yearbook 2012*.

[5] See Report by Economic Times 25 Nov 2013.

Table 4.4 Capacity of hot water supply, Beijing as compared with the nation, million w

	China	Beijing	%[1]
2000	97,417	4,755	4.9
2005	197,976	30,115	15.2
2007	224,660	28,989	12.9
2008	305,695	31,772	10.4
2009	286,106	32,674	11.4
2010	315,717	35,684	11.3
2011	338,752	36,805	10.9

Notes: 1. Percentage of All China.

Source: NSB 2012, *China Energy Statistical Yearbook 2012*.

Gas Prices and Subsidies

The low and distorted home gas prices have discouraged gas production and imports. According to the 12th Five-year Gas Plan, China's home gas prices have failed to reflect relative scarcity of gas. On the other hand, the government may have to raise gas prices gradually, considering the incomes and affordability of gas users. A rapid increase in gas consumption may lead to increased government subsidies on gas, without corresponding price hikes. In the first three quarters of 2013, Petrol China lost RMB 31.6 billion from the sales of imported gas, and the loss was made up partly by an increase in the retail prices of gas.[6]

Beijing has subsidized residential uses of gas. The price differentials as shown in Table 4.5 indicate that the municipal government has subsidized residential uses of gas. An effort has been made by the government to reduce price distortions and subsidies. The residential gas price, which was set at RMB 2.05 cubic meter in 2007, was raised to RMB 2.28 cubic meter in December 2012. [7]

Table 4.5 Gas prices for different uses, Beijing, RMB/cubic meter

Gas Uses	Prices
Residential	2.28
Industrial uses	3.23
Public services	3.23
Power generation[1]	2.67
Compressed natural gas	
Main station	2.62
Retail outlets	5.12

Notes: 1. Including power for heating and cooling.

Source: NDRC 2013, Document No 1967, Beijing.

[6] See 'Petrol China is going to face the most serious shortage in gas supply', China Security Daily, 1 November 2013.

[7] See 'The price for residential use of gas to increase by RMB 0.23 per cubic meter from 1 Dec, Xinhua News Agency, www.news.cn, 1 December 2012.

Energy Planning Before and After the Action Plan

Gas consumption in Beijing is set to double in the next 3 years. Recently, the National Development and Reform Commission (NDRC) revealed an ambitious plan for raising Beijing's gas consumption in the next three to four years to facilitate a strategic shift from energy security to energy security plus clean energy use. According to Table 4.6, the share of gas in Beijing's total energy consumption will rise from the current 14% to 35% in 2017, an increase of 11 ppts and the share of coal will fall from 24% in 2013 to 10% in 2017, a fall of 14 ppts. As a result, coal use is set to fall by 10 million tons and gas will become the most important source of energy for Beijing.[8] According to 'Beijing Clean Air Action Plan Tasks 2013-2017' published on 2 September 2013, the Beijing municipal government plans to raise gas consumption from about 10 bcm in 2013 to 24 bcm in 2017.[9] According to expert estimation, gas consumption in China is expected to hit 350 bcm by 2017 and 450 bcm by 2020.

Table 4.6 Planned changes in energy consumption, 2013-2017, %

	2013	2017
Total energy use	100	100
Gas	14	35
Electricity	n.a.	30
Coal	24	10

Source: China Economic Times, 25 Nov 2013.

Infrastructure projects accelerated to accommodate the projected growth in gas consumption. Petro China provided 90% of Beijing's gas, with piped gas from the Changqing Oilfield in Shaanxi and Gansu provinces, the Tarim Oilfield in Qinghai Province and gas from Central Asia. According to the head of the Gas Pipe Corporation under Petro China, the six newly built or upgraded gas pipelines have the capacity to supply 16 bcm gas to Beijing from 1 November 2013 to 30 March 2014. To increase gas supply, for the first time, Beijing is going to import LNG from Qatar. Beijing has already constructed ports and storage to accommodate 3.5 million tons of LNG from Qatar through the East China Sea (equivalent to 4.725 bcm gas) each year. More ports and storage facilities will be built in the future for LNG. LNG imports aim mainly at making up temporary gas shortages caused by extreme winter weather conditions. It takes about 17 days to transport LNG from Qatar to Beijing and takes less than 2 days to unload the LNG and connect them to the pipelines.[10]

Escalating air pollution in Beijing has triggered off the projected jump in Beijing's gas consumption. Our interviews with the officials from the NDRC and Ministry of Industry and Communication indicate that the Beijing municipal government, together with the local governments in Tianjin and Hubei Province, has been under growing pressure to reducing air pollution (PM 2.5) in Beijing and surrounding areas. The Party's Organizational Department has just released an announcement to change the performance assessment criteria for local governments and officials: to reduce the weight of GDP and income growth in the assessment and to raise the

[8] According to the speech by Mr. Liu Yinchun, the Deputy Chairman of Beijing NDRC at the Beijing Energy Conference on 23 Nov 2013, reported by China Economic Times (Zhongguo jingji shibao) on 25 Nov 2013 and also posted on the website of Beijing Gas Corporation: www.bjgas.com.

[9] The Action Plan was issued by Beijing Government and is posted on the government website: zhengwen.beijing.gov.cn.

[10] See 'Six pipelines sending 16 bcm gas to Beijing', Beijing Daily, 25 November 2013.

weight for pollution control, and environment and resource protection.[11] Compared with other options to reduce air pollution, such as vehicle pollution and pollution from steel mills in the Hebei Province, to substitute coal with gas faces less resistance and hence could be achieved in a relatively short period of time. Another cause for the projected increase in Beijing's gas consumption is the increase of more extreme weather conditions in Beijing.

Further Notes on the Beijing and Hebei Action Plans

The recent Beijing Action Plan includes, for example details of a new natural gas pipeline and gas infrastructure to ensure the city has gas supplies of 24 bcm by 2017.

Infrastructure plans include:

- in 2013 construct stage one of the Datang Coal to Gas project and Tangshan LNG project;
- by 2015, fully complete the fourth Shaanxi-Beijing gas line, the Datang Coal to Gas project, the Tangshan LNG project and connect up 10 suburban towns with the natural gas pipeline;
- by 2016, construction of the fifth Shaanxi-Beijing gas line will commence to ensure the city has a comprehensive gas supply network; and
- by 2017, the city should have secured 24bcm of gas supplies.

Thermal power plant reforms include:

- implement the conversion from coal to gas for thermal power plant generation;
- in 2013 establish four large natural gas thermal power-heating (cogen) centres in Beijing:
  - SE and SW gas cogen centres will be operational;
  - two new gas cogen units built in NW; and
  - NE gas heating units completed and closure of coal-heating system at Keliyuan;
- in 2014 the NW and NE gas cogen units will be operational and the remaining Gaojing coal thermal plant will be closed down;
- **in 2015, the new gas-fired generators at the Huaneng Beijing thermal power plant will be** put into operation and the coal fired units at the Guohong Beijing Cogeneration Plant will be closed down;
- in 2016, the remaining coal-fired units at the Huaneng plant will be shut down;
- the remaining residential areas (260,000 households) relying on coal for heating will be converted to electricity-based or cogen thermal heating;
- by 2015 the core area of Beijing will be coal free;
- by 2016, rural and suburban areas will be connected up to gas cooking to replace coal;
- in 2013, stricter monitoring will be carried out to ensure coal supplies are clean and coal is transported appropriately;
- by 2012-2017 reach an energy intensity reduction of 20%;
- ensure 75% of new residential buildings meet the energy efficiency standards; and
- existing residential buildings are to be retrofitted so that 50% of stock meeting energy efficiency standards.

[11] See: 'An Announcement by the Organizational Department of the Central Committee of the Communist party's China', reported on the People's Daily website: www.people.com.cn, 10 December 2013.

The Hebei Implementation Scheme of Action Plan of Air Pollution Prevention and Control (September 2013) (河北省《大气污染防治行动计划实施方案) includes the following points:

- limits on industrial pollution including key polluting sectors of iron, cement, electricity and glass (contribute 60% of Hebei's SO_2 and 53% of coal use – 167mt);
- reduce production of:
  - iron and steel by 60 million tons and 40 million tons of coal consumption by 2017 (compare this with 3 key region target of 15 million tonnes of iron and steel production by 2015);
  - 61 million tons of cement capacity will be closed;
  - 1.8 million tonnes of glass by 2018; and
- spending of RMB 291 million will be undertaken to establish a real time comprehensive AQ monitoring network.

PAPER 5
A Low Coal, High Gas Scenario by 2020

This paper describes the alternative, high gas scenario to 2020, the practicality of which is analysed in this report, and the assumptions that have been used in assembling it. While this particularly specification of a high gas scenario has no special status, it is useful to work with a coherent numerical framework, which ensures that the issues are discussed on a consistent basis. Unless otherwise stated, the units used in tables 6.1 and 6.2 below are the units commonly used in Chinese energy statistics, namely million tonnes of standard coal equivalents (mtce). These units differ, for example, from those used by the IEA, which are million tonnes of oil equivalent (mtoe). Much of the national and international discussion of natural gas is in terms of billion cubic meters (bcm), and the conversion factor used here is that one bcm of natural gas is equal to 1.330 mtce of gas.

Table 5.1 Energy consumption by fuel source, China, 1990-2010 (actual) and 2010-20 (scenario), million tonnes of standard coal equivalent and %

	Coal	Crude oil	Natural gas	Renewables	Total	Memorandum item – Natural gas (bcm)
1990	752	164	21	50	987	16
1995	979	230	24	80	1,312	18
2000	1,007	323	32	93	1,455	24
2005	1,671	467	61	160	2,360	46
2010	2,210	616	142	280	3,249	106
2011	2,380	647	174	278	3,480	131
2012	2,409	680	188	340	3,617	141
2015	2,580	664	300	456	4,000	226
2020	2,820	615	565	700	4,700	425
Average annual percentage change (%)						
2002-12	8.3	6.7	17.3	11.3	8.5	17.3
2007-12	3.9	5.2	15.2	12.3	5.2	15.2
2012-15	2.3	-0.8	16.8	10.3	3.4	16.8
2015-20	1.8	-1.5	13.5	8.9	3.3	13.5
2012-20	2.0	-1.3	14.7	9.4	3.3	14.7

Source: China National Statistical Bureau, accessed through CEIC.

The key assumptions used in constructing this scenario are as follows:

- *Total energy consumption*. The Chinese Government has announced a commitment to a cap on total energy consumption of 4000 mtce in 2015, which implies growth of 4.3% in energy consumption over 2010-15 and of 3.4% per annum over 2012-15. We assume that this 2015 target is met and that energy use grows at 3.3% per annum over 2015-20. This would imply a 19% reduction in energy use per unit of GDP over 2012-20.
- *Coal and oil use*. In 2012 coal provided 66.6% of China's energy consumption and oil provided 18.8%, with a 12th Five Year Plan target for the coal share to fall to 65% by 2015. We assume that, with the focus on substantially reducing air pollution, China will need to reduce the coal (and oil) share more rapidly than previously anticipated, and to at least stabilize coal use in absolute terms by 2020. Stabilizing coal use by 2020 implies, on this energy use scenario, a coal share of about 60% by 2020. These assumptions mean growth in the consumption of coal of 2.0% per annum over 2012-20, by comparison with 8.3% per

annum over 2002-12, and a stable level of coal use in 2019 and 2020. The absolute level of oil use is assumed to fall before 2020, with oil providing 13.1% of energy consumption by 2020. In total, coal and oil would provide 73.1% of China's energy use in 2020, down from 85.4% in 2012. This is a continuation of an earlier trend – in the previous eight years the combined share fell by 5.4 percentage points – but a sharp acceleration of the pace of decline.

- *Renewables*. The growth in renewable sources of energy – hydro, nuclear, wind and solar – has been an important feature of the Chinese energy system over the past decade. Renewables already provided 7.3% of China's energy use in 2002 but grew by 11.3% per annum over 2002-12 and provided 9.4% of total energy use in 2012. The Government has a commitment to bring renewables to 11.4% of the total by 2015 and to 15% by 2020, and is pursuing aggressive policies to ensure that this is achieved. We assume here that they are achieved, implying 9.4% per annum growth in energy from renewable sources over 2012-20.
- *Natural gas*. The natural gas figures both balance the other assumptions made and are consistent with advice from within the Chinese Government that, in the wake of the Action Plan, a target for consumption of natural gas of 400-450 bcm in 2020 is likely to be adopted. Natural gas use has grown by 15.3% over 2002-12, but from a low base. The assumption of a 425 bcm figure for 2020 implies growth over 2012-20 of 14.7%, but from a much higher base level.

Table 5.2 Shares of energy consumption by fuel source, China, 1990-2010 (actual) and 2010-20 (scenario), %

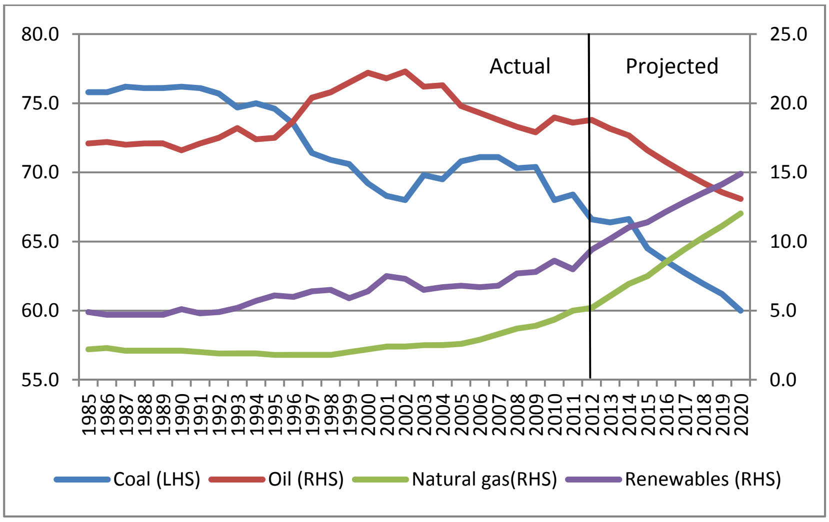
	Coal	Crude oil	Natural gas	Renewables	Memorandum items	
					Gas & renewables	Coal & oil
1990	76.2	16.6	2.1	5.1	7.2	92.8
1995	74.6	17.5	1.8	6.1	7.9	92.1
2000	69.2	22.2	2.2	6.4	8.6	91.4
2005	70.8	19.8	2.6	6.8	9.4	90.6
2010	68.0	19.0	4.4	8.6	13.0	87.0
2011	68.4	18.6	5.0	8.0	13.0	87.0
2012	66.6	18.8	5.2	9.4	14.6	85.4
2015	64.5	16.6	7.5	11.4	18.9	81.1
2020	60.0	13.1	12.0	14.9	26.9	73.1

Source: China National Statistical Bureau, accessed through CEIC.

The scenario expressed in tables 6.1 and 6.2 and in Figure 5.1 is, as has been already noted, one that is consistent with past trends, but which involves a sharp acceleration in the speed of those trends, particularly in the rise in the share of natural gas and the reduction in the coal share of total energy use. This theme is also evident in Figure 5.1.

This report investigates the various questions that arise about whether China could indeed achieve 12% of its energy provided from natural gas by 2020. While the rhetoric about changing the energy system to quickly address pollution implies such a reduction in the coal (and oil) share, and indeed an absolute reduction in coal use, such a reduction will have many costs and will challenge many vested interests. With new coal plants and other facilities still being built, seriously reducing the coal share will require closing down many coal power plants and other facilities which still have considerable economic life remaining, which will involve heavy capital losses. Whether this proves possible, in the face of conflicting forces and vested interests, remains to be seen.

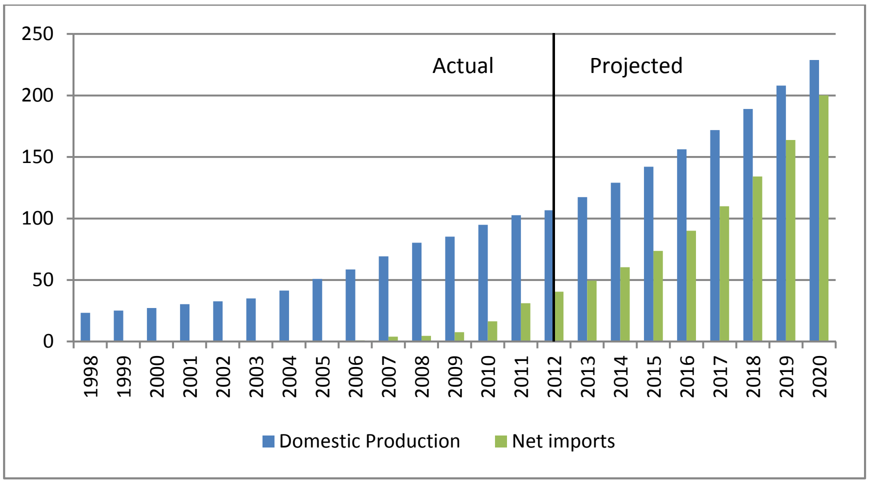
Figure 5.1 Share of total energy consumption by fuel group, China, 1985-2012 (actual) and 2012-2020 (scenario projection), %



Source: China National Statistical Bureau to 2012, and projections of the authors.

Finally, the scenario specifies a broad split between China's domestic production of natural gas and imports, whether by pipeline or LNG, out to 2020, in achieving the gas consumption figure of 425 bcm in that year. Domestic production has grown by 12.6% per annum over the past decade (2002-12) and reached 106 bcm in 2012, while imports were about 40 bcm. We analyse in this report the factors influencing domestic production of different types of natural gas and different sources of imports. The scenario, provided for assessment, assumes that domestic production rises at 10% per annum over 2012-20 to reach about 225 bcm in 2020, which requires imports to reach 200 bcm by 2020. These trends are illustrated in Figure 5.2.

Figure 5.2 China's domestic production and imports of natural gas, 1998-2012 (actual) and 2012-2020 (scenario projection), bcm



Source: China National Statistical Bureau to 2012, and projections of the authors.

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COMMENTARY:

China's response to the air pollution shock

Peter Sheehan, Enjiang Cheng, Alex English and Fanghong Sun

Faced with serious air pollution, China is aggressively reshaping its energy system, building on recent progress with renewables and on available supplies of gas. This should help contain global warming and provide new impetus to climate change negotiations.

Over the past decade China accounted for over two-thirds of the growth in global CO_2 emissions from energy use. In 2012, its emissions far surpassed those of other major countries and regions[1] (Fig. 1). This reflects rapid economic growth in a massive country whose energy system remains largely based on fossil fuels, despite strong progress in renewable energy. This emissions growth has long spelt danger for the global climate. A gradual process to halt the rise in China's emissions by 2030 will alone add over 10% to the already high global level of CO_2 emissions from energy use in 2012. China's response to the air pollution crisis suggests that its government is taking action that will bring emissions under control much more abruptly than previously evisaged. Such a rapid process could improve prospects of holding global warming to less than 2°C and have important implications for both climate modelling and international climate negotiations.

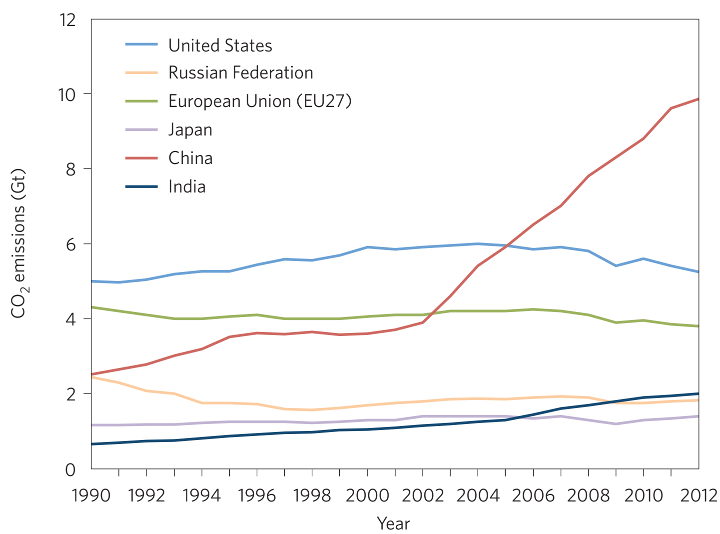

Figure 1 | CO_2 emissions from fossil-fuel use and cement production for selected countries and regions. Figure reproduced from ref. 1.

China's pollution shock

During 2013, air pollution in China became a major economic and social issue across the country ('the pollution shock'). In January 2013, thick smog blanketed Beijing and northern China, covering 2.7 million square kilometres and affecting more than 600 million people. Although varying with weather and other factors, air pollution remained high in many parts of China throughout 2013. It reached extreme levels in Harbin in October 2013 and in Shanghai, normally a city with fairly good air quality, in December 2013. Many cities, including Beijing and Shanghai, experienced a return of heavy air pollution in January and February 2014.

The central concern is with fine particles less than 2.5 micrometres in diameter ($PM_{2.5}$). These pose the greatest health risks, lodging deeply in the lungs and leading to increased risk of pulmonary and cardiovascular disease and cancer. $PM_{2.5}$ levels are measured in micrograms per cubic meter (μg m^{-3}). The WHO guideline for the maximum safe level is 25 μg m^{-3} for a 24 hour period and 10 μg m^{-3} on an annual basis[2]. Readings in excess of 500 μg m^{-3}, twenty times the recommended WHO 24 hour level, have become common in many Chinese cities in periods of heavy pollution, with higher spikes occuring on some days. According to official data, average $PM_{2.5}$ levels for 2013 were more than five times the WHO annual maximum level in 58 Chinese cities[3].

Several factors contributed to increasing concern within China. One is the growing realization of the health threat from fine particles, especially at the levels being seen in China. Another is the evident impact of air pollution on people's lives — schools and factories were closed, warnings were issued for the young and elderly to stay indoors, flights were cancelled and so on. A third is the open availability of data, with most cities now collecting and publishing real-time data. On 12 February 2014, the State Council Executive Committee acknowledged the "grave situation" generated by air pollution, which is "cumulative for a long period of time"[4]. Air pollution has become a national emergency.

The Government's response

The Government's response to this crisis started with the 'Action Plan for Air Pollution Prevention and Control (2013–17)', issued by the State Council on 10

Table 1 | Energy consumption by fuel source in China.

	Coal	Crude oil	Natural gas	Renewables	Total	Memorandum item — Natural gas (billion m³)
Actual						
1990	752	164	21	50	987	16
2000	1,007	323	32	93	1,455	24
2005	1,671	467	61	160	2,360	46
2010	2,210	616	142	280	3,249	106
2012	2,409	680	188	340	3,617	141
Scenario						
2015	2,580	664	300	456	4,000	226
2020	2,820	615	565	700	4,700	425
Target						
2030	2,616	545	930	1,364	5,455	700

Values are in millions of tonnes of standard coal equivalent, unless otherwise stated. Here, renewables include nuclear energy. Data taken from ref. 9 and from estimates made by the authors.

September 2013[5]. The plan targets marked improvement in air quality over the five years to 2017, focusing on three regions that account for 40% of China's GDP: the Beijing–Tianjin–Hebei region, the Yangtze River Delta and the Pearl River Delta. The plan includes mandatory 25% reductions in annual average concentrations of $PM_{2.5}$ by 2017 in Beijing, 20% in the Yangtze River Delta, 15% in the Pearl River Delta and 10% in other key cities.

Crucially, the plan recognizes that achieving these targets requires a transformation of the energy system. For the first time, there is a ban in these regions on new coal power plants and sharp cutbacks in coal consumption and steel production. For example, steel-making capacity in Hebei province, producing one quarter of China's steel, will be reduced by 80 million tonnes by 2017. Heavily polluting vehicles are to be removed from the regions by 2015 and nationally by 2017. The Euro V equivalent fuel standards (petrol and diesel) will be introduced in the regions in 2015 and nationally by 2017. Non-fossil energy resources will rise from 9.4% of total energy consumption in 2012 to 13% by 2017, and there will be increased emphasis on natural gas.

The implementation of this plan is continuing, through detailed local plans and through penalties for cities and officials failing to reach targets. For example, in September 2013 the Beijing government announced that the share of gas in total energy consumption would rise from 14% to 35% over the period 2012–2017, with the share of coal falling from 24% to 10%[6]. In January 2014, the Guangdong provincial government announced that the coal and oil share would fall from 72.2% in 2010 to 60.6% in 2015, with the gas share more than doubling to 13.2%[7].

On 12 February 2014, the Director of the Development Research Center (DRC) of China's State Council provided an unusually frank insight into the Government's objectives[8]. In addition to slower growth in overall energy use, he indicated specific targets: the coal share to be reduced from 66.6% in 2012 to 60% in 2020 and below 50% in 2030; renewables to rise from 9.4% in 2012 to 15% in 2020 and 25% in 2030 and gas to rise from 5.2% in 2012 to 10% in 2020 and 15% in 2030. He also outlined plans for a new, low-carbon approach to urbanisation.

Achieving abrupt change

We test whether these abrupt changes are achievable by examining one illustrative scenario through 2020, largely based on the DRC targets but with an earlier shift to natural gas (Table 1 and Fig. 2). This scenario involves a slower growth rate in energy use, a fall in the coal and oil shares in total energy use to 60% and 13% respectively by 2020, and a rise in the renewables and gas shares to 15% and 12% by 2020 respectively. Figure 2a shows that the absolute level of combined coal and oil use peaks by 2020, while Fig. 2b illustrates the abrupt nature of the shift in the structure of energy use. Table 1 also shows a projection of this path to 2030, based on the DRC indications.

The key question is whether the shift to renewables and natural gas can be achieved. Strong growth continues in China in the four low-carbon energy sources — solar, wind, hydro and nuclear — particularly wind and solar power. In 2013, installed wind capacity grew by 24.5% and solar capacity more than trebled[9]. Hydro-power capacity is rising strongly, increasing by 12.3% in 2013[9]. Approval of new nuclear plants was suspended in early 2011 after the Fukushima accident, but recommenced in October

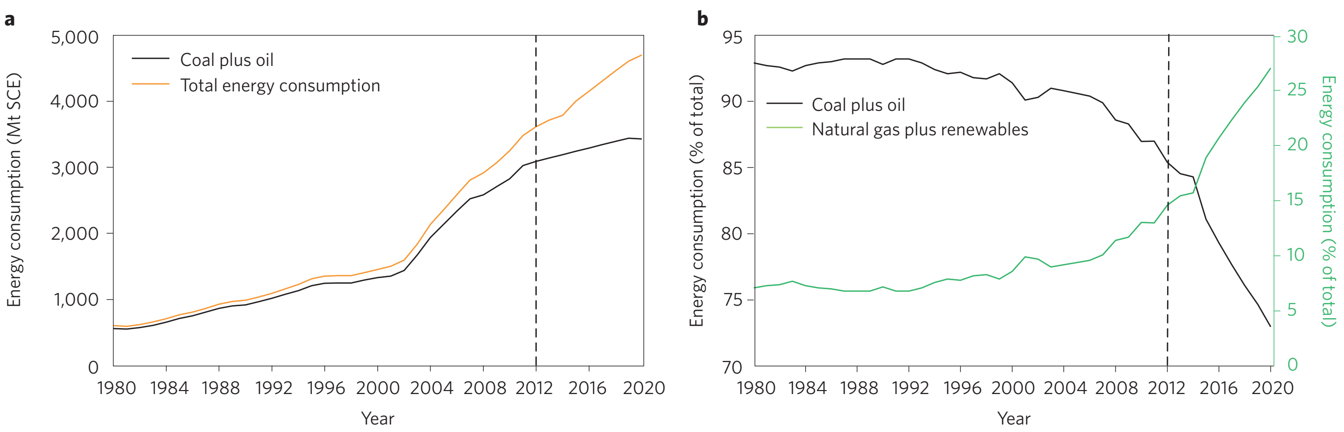

Figure 2 | China's actual and projected energy consumption by fuel type during the period 1980–2020. **a,** Energy consumption by fuel type in China, for the years 1980–2012 (actual) and, to the right of the dashed line, 2012–2020 (scenario). Energy consumption is measured in millions of tonnes of standard coal equivalents (Mt SCE), as defined in the official Chinese statistics. **b,** Share of total energy consumption (%) by fuel type for the years 1980–2012 (actual) and 2012–2020 (scenario). Here, renewables include nuclear energy. Data taken from ref. 9 and from estimates made by the authors.

2012. After no growth in 2012, installed nuclear capacity rose by 16.2% in 2013[9]. A recent review concludes that, provided specific issues such as grid connection and congestion are addressed, China can readily achieve or exceed its renewable energy targets[10].

China is also well placed to expand gas usage, both through domestic production and by taking advantage of the transformation of the world gas market resulting from the explosion of shale gas in the US and increased production of liquified natural gas (LNG) in Australia and elsewhere. Figure 3 shows China's actual and planned gas infrastructure, with a central pipeline structure linking the major markets to domestic gas fields, to providers of gas in East and Central Asia and to a growing network of LNG import terminals along the coast[11].

China's conventional gas production should continue to rise, especially in tight gas, although large-scale production from its substantial reserves of non-conventional gas — shale gas and coal-bed methane — may only occur after 2020. From 2015, China can draw on increased supplies of imported gas, both pipeline imports from countries such as Turkmenistan and Russia and LNG imports from Australia, Russia and Qatar. These imports should be at acceptable prices, as global supply options increase and as US exports of LNG impact on traded gas prices in East Asia. This combination of factors provides China with the opportunity to rapidly expand the use of gas — in areas such as power generation, combined heat and power systems, industry, transport and residential use — to meet the targets outlined in Table 1.

Figure 3 | Natural gas infrastructure in China. This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Reproduced with permission from ref. 11.

Implications for climate change

China's new energy strategy is primarily a response to the air pollution crisis, but will have major implications for greenhouse gas emissions (GHG). There is a large overlap between the sources of $PM_{2.5}$ and GHG emissions[12] (Fig. 4). The primary sources of $PM_{2.5}$ emissions are coal and oil use, while gas and non-fossil fuels generate few $PM_{2.5}$ emissions (Fig. 4a). Coal and oil are the dominant sources of GHG emissions, with gas occupying an intermediate position between these and renewable sources, which have low life-cyle GHG emissions.

If China achieves the 2020 energy scenario in Table 1, CO_2 emissions from energy use should peak by about 2020 and then decline. The transition from coal and oil to gas and renewables will involve many older, highly polluting plants, heating systems and vehicles being replaced by state-of-the-art combined cycle gas power plants, combined heat and power systems and natural gas vehicles as well as by non-fossil energy sources. The gains from eliminating the older coal and oil facilities, in favour of state-of-the-art facilities, should offset the rising emissions from increased natural gas use.

Such an emissions outcome for China would enhance the chances that the world can hold global warming to less than 2°C,

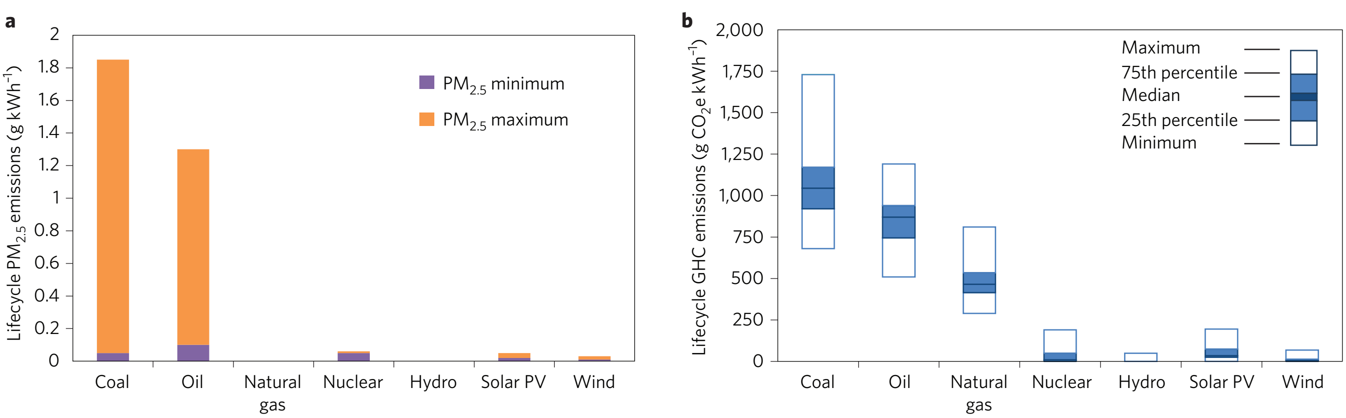

Figure 4 | Lifecycle $PM_{2.5}$ emissions and greenhouse gas (GHG) emissions for selected fuel sources used in power generation. **a**, Lifecycle $PM_{2.5}$ emissions per unit of energy generated (g kWh^{-1}). **b**, Lifecycle GHG emissions per unit of energy generated (g CO_2e kWh^{-1}). Data taken from ref. 12.

and demonstrate an alternative path for countries, such as India, that face rising pollution from development based on coal and oil. China's new energy strategy will also impact on negotiations underway in the United Nations Framework Convention on Climate Change to establish by 2015 a legally binding emissions agreement to apply from 2020.

The main risk to this emissions path would be extensive use of coal-based synthetic natural gas (SNG). With large coal reserves and low coal prices, many see SNG as an important option for China. Many SNG projects have been proposed, some have been approved and a few are operating. But for electricity generation, SNG has lifetime GHG emissions well above coal and, for vehicle use, emissions are well above oil[13,14]. SNG plants are also water intensive, requiring more than six litres of water per cubic metre of gas produced[14]. A big SNG push would undo some of the GHG emissions benefits resulting from the Action Plan[5]. However, the Plan was notably cool on SNG plants, requiring strict enforcement of environmental controls and tight monitoring of water resources. China's severe water shortages might prevent a major expansion of SNG. ❐

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