



Improving Air Quality in Large Cities By Substituting Natural Gas For Coal in China--Economic Barriers and Environmental Policy Analysis

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Abstract. With the fast economic development and large quantity of coal burning, China has been faced with serious coal-smoke pollution in urban area. Natural Gas, although not the dominant energy in China, has been becoming one of the most attractive clean energy. To push forward natural gas penetration, barriers in the way to such penetration are first revealed in this paper by investigating demand and supply sides of natural gas in China's premature market. The discussion starts from looking into natural gas resource and city consumption situation. Some statistic data shows that the average consumption of natural gas in China is lower than other countries. Detailed economic analysis to different municipal consumers gives answer to why natural gas is not welcome for some of them, that is, there exist some barriers on natural gas substitution for coal, including high natural gas price, high cost to change boilers, high additional expenditure, such as initial installation fee or gas source fee, which exert natural gas consumers too heavy burden. Due to these existing systematic barriers on natural gas penetration, some policy indications could be drawn. First, market oriented system reform in natural gas production and retailing system should be considered as a good expectation. Second, governmental allocation plan should be apt for municipal use and restraining charge on municipal consumers should be canceled. Third, foreign and private capital should be attracted into former strict state-controlled natural gas production, transportation and municipal distribution infrastructure regime, to solve the capital shortage problem in most Chinese cities. Finally, relevant environmental economic policies are also expected to take effect in the process, by exert high pollution charge on dirty fuel such as coal, and subsidy on clean fuel consumption.

Keywords: Air Pollution, Natural Gas Penetration, Policy Analysis

1. Introduction

In recent years, urban air quality in China was seriously poor. According to *The State Bulletin of China's Environment 1998 (SEPA, 1999)*, the air pollution in China was mainly from coal-smoke, with the major pollutants

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of SO₂ and TSP. From the monitoring result of 322 cities in 1998, annual daily average concentration of TSP was between 0.011-1.199 mg/m³, and the average value across the country was 0.289 mg/m³. Annual daily average concentration range of SO₂ was between 0.002-0.385 mg/m³, and the average across the country was 0.056mg/m³. Figure 1 shows the air quality in some major cities in China and the world in 1995. Generally, China's urban air quality is much worse than that of other famous large cities in the world.

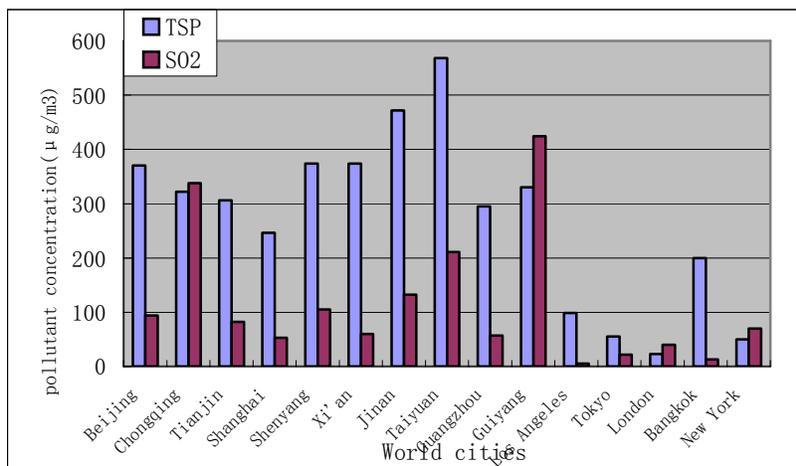


Figure 1 Air pollutants concentration in some major large cities in China and the world in 1995 (SEPA, World Bank, 1996)

The very special energy structure is responsible for the serious air pollution in China. 90% of SO₂ emission was from coal combustion and 73% of smoke dust was from energy consumption. China is one of the 3 countries (China, South Africa and Poland) with coal consumption exceeding 70% in energy structure. Of the total primary energy consumption, coal amounted to 75% in 1996, oil was 17.2%, hydro-power and nuclear power 5.87%, and natural gas (NG) only 1.88%. In contrast, the coal just accounted to 22% in the energy consumption in developed countries, and the weight of NG is over 26%(Chen, 1999). Primary energy structure in some countries is shown by Figure 2. In addition, coal is used for heating and cooking by residential and commercial consumers in most Chinese cities, causing a wide range of indoor and outdoor air pollution problems.

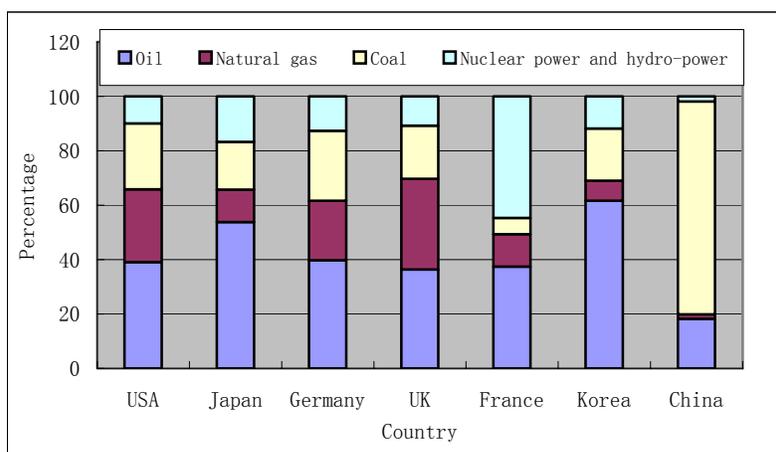


Figure 2 Primary energy structure in selected countries (1996) (Wang, 1997)

Natural Gas is a high quality energy, with high efficiency, low pollutant content and pollutant emission. When consumers substitute natural gas for coal, the emissions of smoke-dust, SO₂, NO_x and CO can be reduced dramatically. Figure 3 shows the pollution emission reduction effect of 100 million m³/yr natural gas substitution for coal in Beijing.

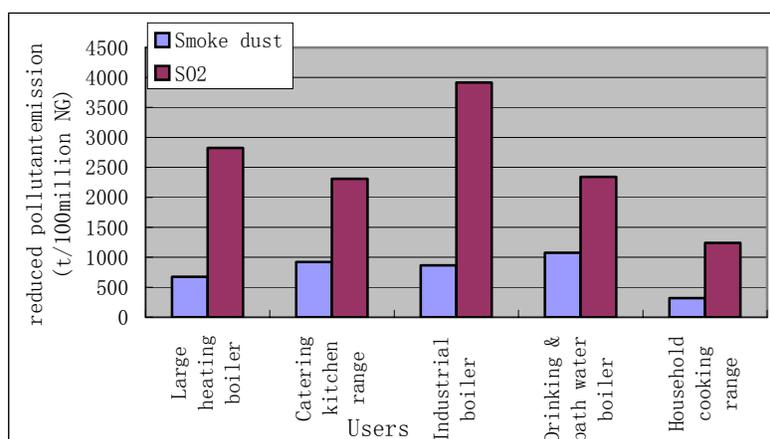


Figure 3 Pollutant emission reduction effect of natural gas substitution for coal (Beijing Academy of Environmental Sciences, 1998)

Terminal demand in natural gas market is much smaller than natural gas production. Between 1991 and 1995, the annual rate of newly discovered natural gas reserve increase reached 11%, while natural gas production and consumption only increased by 2% annually. The average NG consumption in China is much smaller compared to countries (see Figure 4).

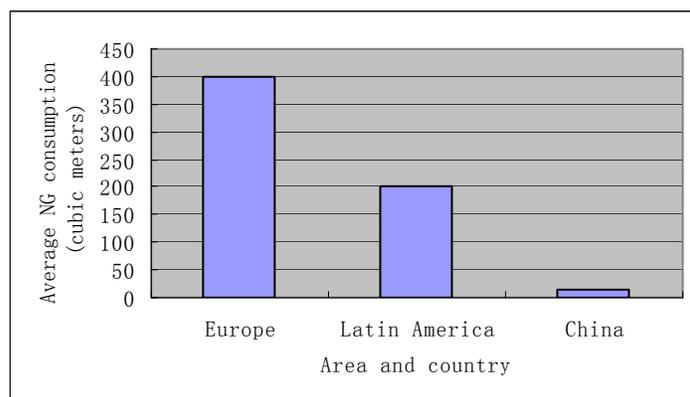


Figure 4 NG per capita consumption in selected places in 1997

From the above, we know that urban air quality in China is so serious, but natural gas as a clean energy, which can be reduce air pollution dramatically, not been extensively penetrated in urban life. Why is this situation? Which factors are blocking the natural gas penetration? Some authors also pay attention to the necessity of increasing natural gas consumption, and they've given some policy suggestion. But they haven't done integrated economic analysis to reveal the real reason and given good environmental economic policies (Zhang, 1998; Yang and Dai,1998; Yang, 1998). This paper will look for the barriers to natural gas penetration by economic analysis to supply and demand of natural gas, and present some policy implications.

2. Supply and Demand of Natural Gas

2.1 Supply of Natural Gas

Although coal and petroleum dominate China's energy structure, there is still large quantity of natural gas resource available in this country. According to the latest data released, China holds 38 trillion m³ of natural gas resource, and 10.5 trillion m³ of exploitable reserve. Many Chinese geologists believe that there is far more natural gas remaining to be discovered given the country's large reserves of coal and oil. Complicated geology, remote locations, and incomplete survey have made it difficult to identify and develop gas reserve in China.

China has announced plans to build liquefied natural gas (LNG) import facility in Guangdong. The world is currently oversupplied with LNG because new supply facilities are coming on-line while demand from Japan and Korea has been falling due to economic slowdown. Capital costs to build new LNG supply trains have fallen by up to 40% this decade (Sandison, 1999). China is now considering construction of additional LNG terminals in Fujian and Shanghai. In addition, some of the world's richest gas fields lie less than 3,000 kilometers away from Beijing in Siberia, near Irkutsk. Gas from these fields would, however, be China's cheapest import option. Discussions are also underway for pipeline gas imports from Sakhalin and Kazakhstan. (Jeffrey and Luo, 1999).

2.2 Demand of Natural Gas

To examine the financial burden of using natural gas from the point of view of consumers, the change of financial burden on consumers who have substituted natural gas for coal is calculated. Three aspects of cost increment should be considered, i.e. fuel price, equipment expenditure and operation cost.

2.2.1 Relatively high price of Natural Gas

Natural gas substitution firstly means increment of fuel expenditure, for that natural gas is much more expensive than coal in terms of price per unit of thermal value. The average coal price in China is 279.5 CNY/ton (for coal of calorific capacity 6200 kcal/kg) and 271.09 CNY/ton (for coal of calorific capacity 6000 kcal/kg). However, in Chongqing and Beijing, the local coal price is lower than this level. In Chongqing, the high sulfur-content coal is only priced at 150 CNY/ton in the local coal market, which makes coal a very strong competitor to natural gas. Annual demand of coal in Beijing is 2.8 million tons. Of which, 1/3-1/4 is sold by Beijing Coal Corporation, and the remaining by collective or individual sellers. Coal price of collective and individual sellers is 220 CNY/ton, 20-30 CNY/ton cheaper than the price of coal corporation, converting into 0.04 CNY/1000cal.

In terms of natural gas, the caloric capacity of Shanganning natural gas is 35615 kJ/m³, equivalent of 8479.76 kcal/m³. At present, the entrance price (natural gas transported to Beijing gas storage station) of Shanganning natural gas is 0.99 CNY/m³, of which the transportation cost is 0.74 CNY/m³. The end-user selling price is 1.4 CNY/m³ for residential use, 1.8 CNY/m³ for industrial use, converting into 0.17 CNY/1000kcal and 0.212 CNY/1000kcal. Table 1 shows the comparison of the price of NG and coal in Beijing and international market.

According to the above Table, the price of natural gas in Beijing is higher than that in Europe and America, approximately the same as that of LNG in Japan. Thus it seemed that natural gas price is one of the impeding factors for natural gas deployment.

2.2.2 Cost of changing combustion equipment

Substituting natural gas for coal also means to replace coal boilers by natural gas boilers. This requires big capital input by the consumers. There are two alternatives to change from coal to natural gas. One is to reconstruct the old

coal boiler to natural gas boiler. The other is to replace the old equipment with a new one. Table 2 shows the cost comparison of both options.

Table 1 Price of natural gas and coal in Beijing and international market (WESR, 1997)

Unit fuel	Caloric capacity	Price per kg or m ³	Price per 1000kcal*
Shanxi Coal	6200 kcal/kg	0.22 CNY/kg	0.04 CNY / 1000kcal
Shanganning Natural gas	8480 kcal/m ³	1.40 CNY/m ³	0.17 CNY / 1000kcal
		1.80 CNY/m ³	0.212 CNY / 1000kcal
Japan(LNG)		1.08 CNY/m ³	
Europe		0.71 CNY/m ³	
USA		0.56 CNY/m ³	

*converted to the same thermal unit.

Table 2 Cost comparison of changing coal combustion boiler to natural gas boiler
(installation fee included)

Capacity of boiler	4 ton/hr	6 ton/hr	10 ton/hr
Old coal boiler reconstruction cost (10000 CNY)	31.1	38.9	65
New boiler cost	51	71	120
Saving of reconstruction old boiler (as compared with renewing boiler)	39%	45.2%	46%
Efficiency of reconstructed boiler	88.05%	88.99%	90.31%
Efficiency of new boiler	89%	90%	91%

Most of the cost of reconstructing old coal boilers goes to purchase and equip combustion cell, re-equip flue, automatic control reconstruction, etc. According to the data quoted in the Table 2, reconstruction is a cheaper way if the old coal boilers are in good condition. From this table, it is truly informed that the cost of reconstructing or replacing coal-burning boilers with natural gas burning boilers is high enough to be regarded as a blocking barrier to natural gas penetration.

2.2.3 Total incremental cost for natural gas substitution for different consumers

To examine the financial burden for using natural gas from the point of view of consumers, the change of financial burden on consumers who have substituted natural gas for coal is calculated. The calculation is based on the assumption of 1 billion m³ allocation scenario with reference to the research report of Beijing Academy of Environmental Sciences (1998), as shown in Table 3.

Coal is much cheaper than gas for all the users in the above table except for household (residential) consumers. Therefore, most of users pay much more money after substituting coal for natural gas. However, the natural gas expenditure in total cost of commercial and residential consumers is small (see Table 4), indicating an easy acceptance of the cost increment. But there is surcharge on natural gas consumption, which changed this situation.

Table 3 Annual incremental cost for different users in 1 billion m³ natural gas distribution scenario (10,000CNY/yr)

No.	Users	Household cooking range	Catering kitchen range	Drinking & bath water boiler	Industrial boiler	Large heating boiler
1	Equipment fee ¹	536	139	309	806	611
	Coal fuel fee	16963	2423	3966	32690	12271
	Natural gas fee	11861	10430	11590	90974	51756
2	Fuel cost					
	Cost difference between natural gas and coal	-5102	8007	7624	58284	39485
3	Other saving of facility				460	156
4	Saving of land occupation				354	134
5	Saving of electricity				867	261
6	Saving of water fee					34
7	Saving of labor force					110
8	Saving of ash-slag removal	483	69	113	929	349
9	Pollutant treatment reduction	560	173	230	2744	1020
	Annual cost ²					
10	(3)+(4)+(5)+(6)+(7)+(8)+(9)-(2)	6144	-7487	-6663	-52999	-36894

¹Item 1 only occurs in the first year, so it is not included in annual cost.

²Negative sign means increased cost.

Table 4 Weight of natural gas cost in total budget of consumers

Consumers	Natural gas expenditure in total cost (%)	
Industry	Carbonic ammonium	40%
	Urea	45%
	Other chemical industry	11%
Commercial	Catering	5%
	Hotel	4%
Residential		3%

Source: Jeff D. Makhholm et al, 1995, *Allocation and Pricing of Natural Gas in Sichuan*, National Economic Research Association (NERA) Research report, Chongqing University Press Inc.

2.2.4 “Initial Installation Fee(IIF)” and “Gas Source Fee (GSF)”

Collected by local distribution companies, IIF and GSF are surcharges to natural gas consumers before getting access to natural gas in Chongqing and Beijing, respectively, in addition to normal natural gas price. The initial goal of the surcharge is to collect/accumulate capital fund for natural gas infrastructure construction and development.

This is something born in the special period of economy reformation from traditional planning economy to market economy. However, it is becoming a big obstacle to natural gas deployment now. Table 5 and Table 6 show the GSF in Beijing and IIF in Chongqing.

Table 5 Gas Source Fee for different consumers in Beijing

Consumer type	Households	drinking & bath water boilers and public kitchen ranges	industrial boilers
Charging standard	2,300-2,400 CNY per household	1,200 CNY per cubic meter of daily gas consumption	704,000 CNY per evaporation ton (or 0.7 MW).

Table 6 Initial installation fee and equipment fee standard in Chongqing

Consumers	Initial Installation Fee	Equipment Fee
Domestic(CNY/household)	1200	1000
Business(CNY/m ³ •day)	500	1000
Collective(CNY/m ³ •day)	480	480
Boiler, air-conditioning	exempted	Calculated according to engineering size

In the first year of changing from coal to natural gas for the study case, GSF and IIF amounts to 70-80% of total expenditure increment. Thus, the very high IIF and GSF set a high threshold for the potential consumers with less payment capacity. The economic effect of IIF/GSF is shown in Figure 5.

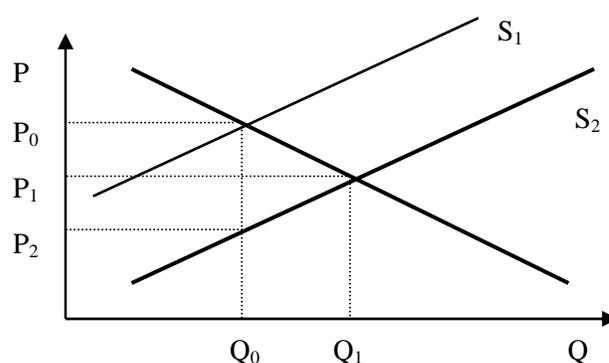


Figure 5 Economic effect of *IIF/GSF*

In Figure 5, the supply curve S_1 represents the current situation, i.e. supply curve with IIF/GSF performing, and its intersection point with demand curve indicates current partial equilibrium point Q_0 . It is clear that if the IIF/GSF is removed, the lower supply curve will apply and the quantity of gas demand will increase due to the lower market equilibrium price. Note that the vertical distance between the two supply curves will depend on how the IIF/GSF is administered. If it is one-off charge, such as the on-going charges in Beijing and Chongqing, the full amount is reflected in the difference between the supply curves. If it is annualized, the impact will be much less.

In addition, for residential consumers with optimal domestic economic expectation but weak payment capability who feel difficult to pay so much one-off charge, *IIF/GSF* sets high access threshold. And for other potential

consumers of commercial and small-scale industrial boilers, this would reduce significantly the attraction of using natural gas.

2.2.5 High cost of urban natural gas pipeline system construction

In the past decades, the upstream natural gas exploration, exploitation and long-distance pipeline system construction project fall into "industrial construction project" management, under the national economic plan. Downstream urban distribution system construction is regarded as urban civil infrastructure construction project. The upstream and downstream infrastructure constructions are planned into two separate systems, leading to difficulties in harmonizing with each other.

Lag of city end-user distribution system may still hinder the terminal consumption even when there is high-pressure pipeline in city gate. End-user distribution system construction is capital intensive and needs large number of financial inputs. Introduction of financial resource from abroad and private investors may be an option to supplement the shortage of urban distribution system construction capital resource.

3. Policy Recommendation

3.1 Policy Making Preference for Residential Use

With limited natural gas resource endowment, and the connatural character of 'natural monopoly' in natural gas industry, especially natural gas transportation, governmental regulation will be in existence in foreseeable future. But governmental allocation should be apt for residential use and, ongoing surcharge on residential consumers, such as '*gas source fee*' and '*initial installation fee*' should be cancelled immediately.

3.2 Open Access of Natural Gas Industry to Private and Foreign Investors

Natural gas industry has always been strictly controlled by the central government, that private and foreign companies were prohibited to be involved in. There has been long time capital shortage in all sectors of natural gas industry. Exploration is insufficient to clarify the potential natural gas reserve. Transportation system has no enough budgets to renew the pipeline, pumping and gas clearing equipments. The municipal natural gas allocation system is short of money to expand branch and sub-branch pipeline system.

To introduce foreign and private capital into natural gas industry would be a good countermeasure. Some foreign companies have been involved in offshore petroleum and natural gas exploration and exploitation in China. Inland cities also need foreign and private capital to participate in natural gas production, transportation and allocation infrastructure construction, in the form of joint venture and joint-stock company.

According to "Foreign Merchant Investment Industry Directive Catalog" issued by State Development Planning Commission (SDPC), State Economic and Trade Commission (SETC), and Ministry of Foreign Trade and Economic Cooperation (MOFTEC), Chinese company must act as holding company in natural gas transportation pipeline projects construction and operation. While municipal natural gas pipeline system is forbidden to foreign investors.

There is some change coming up. On July 12, 2000, the SDPC declared the break through of open policy in 'transporting western natural gas to eastern China' project, that, foreign companies are permitted to join the project as holding company, and the municipal pipeline-network system will also be open to foreign investors (People's Daily, 2000). There are also some other preferential terms for the foreign investors for the project, including deration of prospecting and exploitation fee of natural gas, tax exemption of import equipment, and land requisition policy,

etc. All these show a good start of the reform to right direction.

3.3 Market Oriented System Reform in Natural Gas Industry

Since old planning system in practice in China's natural gas industry has been one of the basic barrier to natural gas penetration, transforming to a more open and flexible system is becoming necessary. Some market-economy countries have undertaken reforms to this aim step by step (see Figure 6). Good examples are UK, USA and Canada (IEA, 1998).

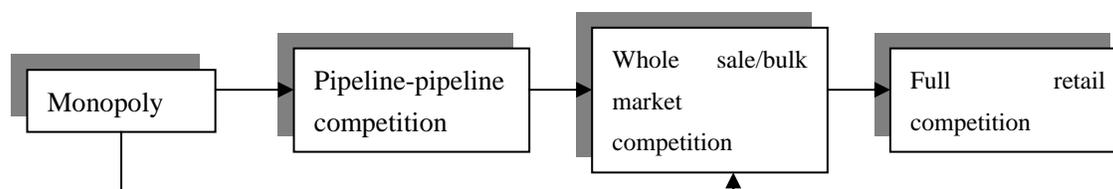


Figure 6 Stages of Development of Gas-to-Gas Competition (IEA, 1998)

Deregulation and market oriented reform require basically that there are more than one supplier in the natural gas market available for choosing, and natural gas supply and transportation service could be separated, so that the consumer can choose the best well-head price and transportation price combination. Since natural gas transportation system will bear natural monopoly, it still must be strictly regulated in case it abuses its privilege. Natural gas pricing approach also changes from the central governmental regulation to market adjustment.

Ideal Natural Gas producing-retailing system should be able to avoid monopoly and be efficient. It is essential to change the monopoly local natural gas distribution company into an entity just responsible for running pipeline network in city zone, under the supervision of municipal government. There should be more than one natural gas retailers, which is the precondition of introducing competition into natural gas market. And the end-user consumers will be able to buy natural gas from their favorite natural gas retailers.

3.4 Environmental Economic Incentive

To encourage natural gas penetration in large cities as residential and commercial fuel, an optional method is to set up economic stimulation system, including discharge fee and tradable emission permits. This can be implemented on natural gas and all the substitutes, especially coal. The stimulation system in discussion should bear the following characteristics: (i) it will lead to stimulation to employ pollution control measurements; (ii) it can guide pollution control activity in a cost-effective way, and (iii) it will reflect the disadvantage of using dirty fuel, such as coal, and make the companies and residents to choose the right fuel.

The government can also choose to subsidize municipal residents according to how much environmental benefit could be produced after changing from coal to natural gas. In contrast, natural gas for chemical fertilizer production should not be subsidized, because there is little incremental pollution if using substitute as raw material, and moreover, there should be taxation on it.

All the decision making on natural gas production and allocation should definitely consider possible environmental damage caused by natural gas substitutes. From the point of view of environmental influence, natural gas supply should be increased. More importantly, environmental consideration will change the relative prices of natural gas in different usages. For example, cooking and heating coal-burning facilities are difficult to be controlled

effectively. Then preference to natural gas substitution becomes very high, especially in cities with high population density. On the contrary, preference to natural gas substitution in coal burning thermal power plant is much lower, especially to those plants with desulfurization facilities and when the plants are located in places far away from cities with low population density.

After September 1999, Beijing EPB raised the emission charge fee for SO₂ emission from coal burning to coordinate the activity of substituting coal for natural gas. According to the new regulation, any coal consumer must pay *pollution charge* of SO₂ at the rate of 0.50 CNY/kg for low sulfur-content coal and 1.20 CNY/kg for high sulfur-content coal. It means whether attaining the emission content standard or not, the charge is required. For oil and gas, the rate is 0.20 CNY / kg.

It can be drawn from Table 7 that even in the raised charge standard of Beijing, the SO₂ emission charge only amounts to a small fraction of consumer's total fuel cost, far from reflecting environmental damage. It will not become a useful tool of incentive measurement to natural gas substitution only until the charge is high enough.

Table 7 SO₂ emission charge to different users in Beijing

Consumer Items	Large heating boiler station	Drinking & bathing water boiler	Catering kitchen range	Household cooking range	Industrial boiler
Pollution charge for SO ₂ (CNY/yr.unit)	133,000	392	128.4	2.2	7,003
Fuel cost					
Coal fuel fee	4010000	19800	7100	480	222000
(CNY/yr) Natural gas fee	16940000	60100	20000	490	643500
Percentage of pollution charge by coal fuel fee	3.32%	1.98%	1.81%	0.46%	3.15%

4. Conclusions

China's large cities have been suffering serious coal-smoke pollution in the past decades, the declining urban air quality has raised the voice applauding to use more natural gas in large cities as a countermeasure to coal-smoke pollution emission. However, in those cities that want to push forward natural gas penetration, there exists wide range of systematic barriers that makes it very difficult a task. To exam those barriers and give the respective incentive policies are two major objectives of this paper. Beijing, the capital of China and Chongqing, the important industrial and commercial city of Southwest China, were selected as two case study cities.

This paper starts from reviewing the general air pollution situation in China's large cities. Then the systematic barrier on the way to natural gas penetration is carefully examined from demand side and supply side. It was argued that in the past decades, natural gas in China has been under-priced under planning economy regime, which has discouraged natural gas exploration and exploitation. Planning economy also leads to arbitrary natural gas allocation policy apt for chemical fertilizer production as raw material and overlooked civil demand. Monopoly of local natural gas distribution company enable it to charge extra IIF and GSF to potential residential natural gas users, plus the price gap between relatively expensive natural gas and very cheap coal, as well as the facility reconstruction cost, make changing from coal to natural gas costly for most of the consumers. Residential and commercial demand of natural gas is high. Detailed economic analysis to different consumers gives answer to why natural gas is not

welcome for some of them. It is the high incremental cost of substituting natural gas for coal, especially the extra governmental charge exerted on natural gas consumers that is hindering further penetration of natural gas in cities. In addition, domestic capital deficiency also holds back the expansion of high-pressure pipeline and urban distribution pipeline network construction, indicating the necessity of introducing foreign capital into natural gas industry in China.

Due to existing systematic barriers on the way to natural gas penetration, some policy recommendation could be drawn:

- With limited natural gas resource endowment, and the intrinsic character of 'natural monopoly' of natural gas industry, governmental regulation will be in existence in foreseeable future. However, governmental allocation plan should be apt for municipal use and restraining charge on municipal consumers should be canceled immediately.
- Insufficiency of municipal natural gas terminal distribution infrastructure is one of the key choking factors. Foreign and private capital should be attracted into former strict state-controlled natural gas production, transportation and municipal distribution infrastructure regime, to solve the capital shortage problem in most Chinese cities.
- Relevant environmental economic policy instruments are also expected to take effect in the process. Ongoing emission charge fee to urban coal consumers emitting SO₂ and TSP has failed to discourage coal burning due to its little punishment effect. This basically means it is necessary to exert higher pollution charge on dirty fuel such as coal, and to subsidize clean fuel consumption.
- Command and control instruments can also take good, instant effects in promoting natural gas penetration in situation. Beijing has significantly improved its ambient air quality in the past two years with forcible regulation of 'non-coal region', under the pressure of 2008 Olympic Games competition.
- When China is transforming from former strict planning economy to market economy, market oriented system reform in natural gas production and retailing system should be considered as a good expectation in long run.

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