Improving Air Quality in Chinese Cities by Substituting Natural Gas for Coal: Barriers and Incentive Policies

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IMPROVING AIR QUALITY IN CHINESE CITIES BY SUBSTITUTING NATURAL GAS FOR COAL: BARRIERS AND INCENTIVE POLICIES

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ABSTRACT

As a result of its rapid economic development and large volume of coal burning, China is faced with serious coal-smoke pollution in urban areas. In large cities such as Beijing and Chongqing, people are clearly suffering the adverse health effects of coal-smoke pollution, with PM-10 and SO_2 as the main pollutants.

Natural gas, although not the dominant energy source in China, is becoming one of the most attractive clean substitutes for coal. On one hand, there is widespread disagreement and doubt about the rationale for burning natural gas instead of using it as a raw material in the chemical industry. On the other hand, the economic advantages of natural gas over clean-coal technology are crucial in deciding whether to promote the use of natural gas as a fuel.

This research has four goals: Firstly, it quantifies the health damage caused by air pollution, particularly coal burining, in Beijing and Chongqing. Secondly, it explores the rationale behind using natural gas for municipal (residential and commercial) energy production through two comparison studies: (a) using natural gas as clean fuel versus using it as a chemical industry raw material, and (b) using natural gas versus clean coal technology. Thirdly, it performs a cost-benefit analysis of urban natural gas substitution projects in Beijing and Chongqing. The evidence indicates that in cities with the most concentrated population and economic activity, natural gas as the municipal energy source has clear environmental benefits in reducing the concentration of non-point and low-level air pollution.

Fourthly, it investigates the demand and supply of natural gas in China's still-developing market economy to reveal barriers to natural gas penetration. The discussion starts by looking at natural gas resources and city consumption of natural gas. Demand conditions are illustrated by net-back prices in the Sichuan basin and a survey carried out in Beijing. Both show that residential and commercial demand for natural gas is high. A detailed economic analysis of different municipal consumers revealed that the reason natural gas is not welcomed by some of them is the high incremental cost of substituting natural gas for coal, especially as a result of the extra governmental charge levied on natural gas consumption. From the supply point of view, our analysis of the so-called

“oversupply” of the past several years has confirmed that this artificial scenario was caused by the old planning system and is not a true surplus.

This report concludes with some policy recommendations on how to reduce existing systematic barriers to natural gas penetration in large Chinese cities.

1. When transforming its planned economy into a market economy, China should focus on creating a retailing system for natural gas production.

2. In view of China’s limited natural gas resources and the natural monopoly inherent in the natural gas industry, policy interventions are recommended in three areas.

    a) The government’s allocation plan should be appropriate for municipal usage and the surcharges levied against municipal consumers should be removed.

    b) Economic instruments should be used to “level the playing field” between coal and gas by levying pollution charges on dirty fuels such as coal and or subsidizing clean fuels.

    c) Command and control instruments could also be effective in promoting natural gas usage. In order to improve its chances of winning the bid for the 2008 Olympic Games, Beijing has greatly improved its ambient air quality over the past two years through the forcible designation of “non-coal regions”.

3. The lack of a terminal distribution infrastructure is one of the key factors inhibiting municipal gas usage. Because of the shortage of capital problem in most Chinese cities, China should make efforts to attract foreign and private investment in the natural gas industry including production, transportation and development of its distribution infrastructure.

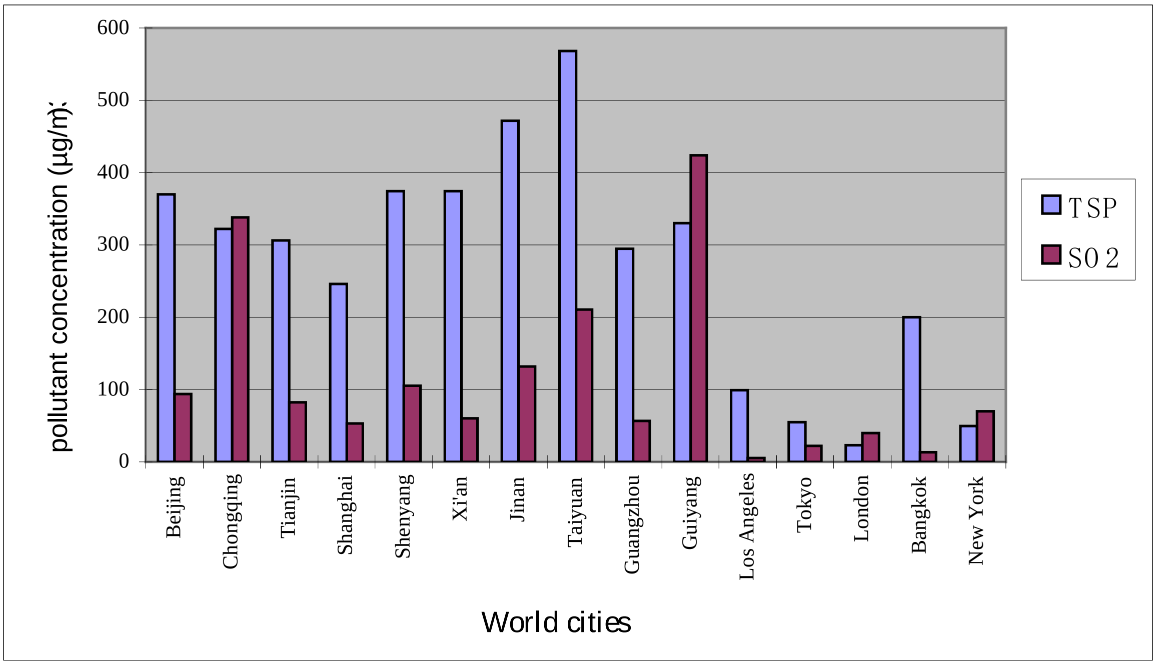
1. 0 COAL-SMOKE AIR POLLUTION AND HEALTH DAMAGE IN LARGE CHINESE CITIES

1.1 Air Pollution in Large Cities

According to The State Bulletin of China's Environment 1998 (SEPA, 1999), air pollution in China in 1998 resulted primarily from coal-smoke, with SO_2 and TSP as the main pollutants. Sulphur dioxide, smoke dust and industrial dust emissions totalled 20,900,000 tonnes, 14,520,000 tonnes and 13,220,000 tonnes, respectively. Sulphur dioxide and smoke dust emissions from daily civil consumption amounted to 4,970,000 tonnes and 2,770,000 tonnes, respectively.

The air environment quality in China’s cities was extremely poor. Three hundred and twenty two cities were monitored in the same year, and it was found that the annual daily average concentration of TSP was 0.011-1.199 mg/m^3, versus the national average of 0.289 mg/m^3. The annual daily average concentration of SO_2 was 0.002-0.385 mg/m^3, versus the national average of 0.056mg/m^3.

Figure 1 compares the air quality of major cities in China with that of selected cities in the world in 1995. Generally, the air quality in the Chinese cities was much worse than in the other cities.

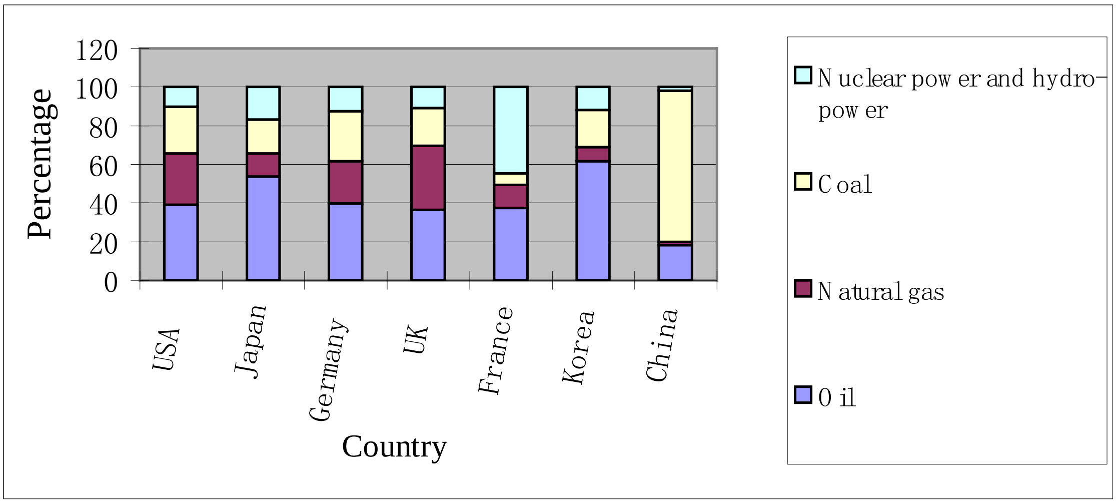


Source: SEPA, World Bank. (1996)

Figure 1. Air Pollutant Concentrations in Selected Major Cities in China and the World (1995)

1.2 The Cause of Air Pollution

China’s energy structure is responsible for the country’s serious air pollution problems. Ninety percent of SO_2 emissions came from coal combustion and 73% of smoke dust from energy consumption. China is one of the three countries (the others are South Africa and Poland) with coal exceeding 70% of the total energy consumption. In 1996, China's coal accounted for 75% of the total primary energy consumption, compared to 17.2% for oil, 5.87% for hydroelectric and nuclear power, and only 1.88% for natural gas. By contrast, in developed countries, coal accounted for just 22% (Chen H., 1999) of the total energy consumption, while natural gas accounted for over 26%. The primary energy structure of selected countries is shown in Figure 2. In most Chinese cities, coal is used by residential and commercial consumers for heating and cooking, causing a wide range of indoor and outdoor air pollution forms.



Source: Wang Q. Energy Policy Study (1997.2)

Figure 2. Primary Energy Structures of Selected Countries (1996)

Beijing and Chongqing, the two case study cities, are typical coal-smoke polluted cities where coal has always been the primary energy source as shown in Tables 1 and 2.

Table 1. Total Consumption of Energy in Chongqing (1998, 1999)

(10,000 tonnes of SCE)

Year	*Total consumption of energy*	*%*	*Coal*	*%*	*Natural gas*	*%*	*Oil*	*%*	*Electricity*	*%*

1998	2,846.94	100	2,020.72	71	291.30	10	183.62	6.4	219.30	7.7
1999	3,256.21	100	2,196.93	67	363.32	11	206.44	6.3	227.68	7.0

Source: Chongqing Statistical Year Book 2000, Chongqing Statistical Bureau.

Table 2. Residential Consumption Per Capita of Energy in Beijing (1998,1999)

Item	*1999*	*1998*
Residential Consumption Per Capita (kg standard-coal)	433.8	416.8
Natural Gas (m^3)	16.3	11.4
Coal (kg)	254.6	289.3
Electricity (kWh)	324.2	269.4
Liquefied Petroleum (kg)	16.8	14.1
Coal Gas (m^3)	19.1	25.3

Source: Beijing Statistical Yearbook 2000, Beijing Statistical Bureau

1.3 Health Damage Caused by Environmental Pollution in Large Cities

The main coal-smoke air pollutants are TSP/PM_{10} and SO_2. They can cause serious damage to human health, crops and buildings and other structures; this consequently results in economic loss.

This research examines the air pollution damage in two Chinese cities, Beijing and Chongqing; the results are presented in Table 3. The damages are estimated following the World Bank Report (1997) valuation, the Ostro model (Ostro B. 1994, 1996) and the Rowe model (Rowe et al. 1995). All three estimation approaches deploy the benefit transfer method (Zhang et al. 1999; Orbeta E.M. et al., 2000). The air pollution damage valuations calculated by the Beijing Academy of Environmental Sciences et al. (1998) and Chang Y. et al. (1996) are also presented for comparison.

The results vary widely. A closer look at the World Bank valuation reveals that the WTP (willingness to pay) valuation method tends to produce much higher estimates than the human capital valuation method. Valuations based on Ostro’s (1994, 1996) and Rowe’s (1995) models ignore the impact of the difference in income levels between developed and developing countries on WTP, (i.e. the income elasticity of WTP). In Ostro’s (1994, 1996) valuation, the central and high values seem too high to be reliable. The other estimates, however, appear to be in an acceptable range.

Table 3. Estimated Annual Air Pollution Damage in Beijing and Chongqing

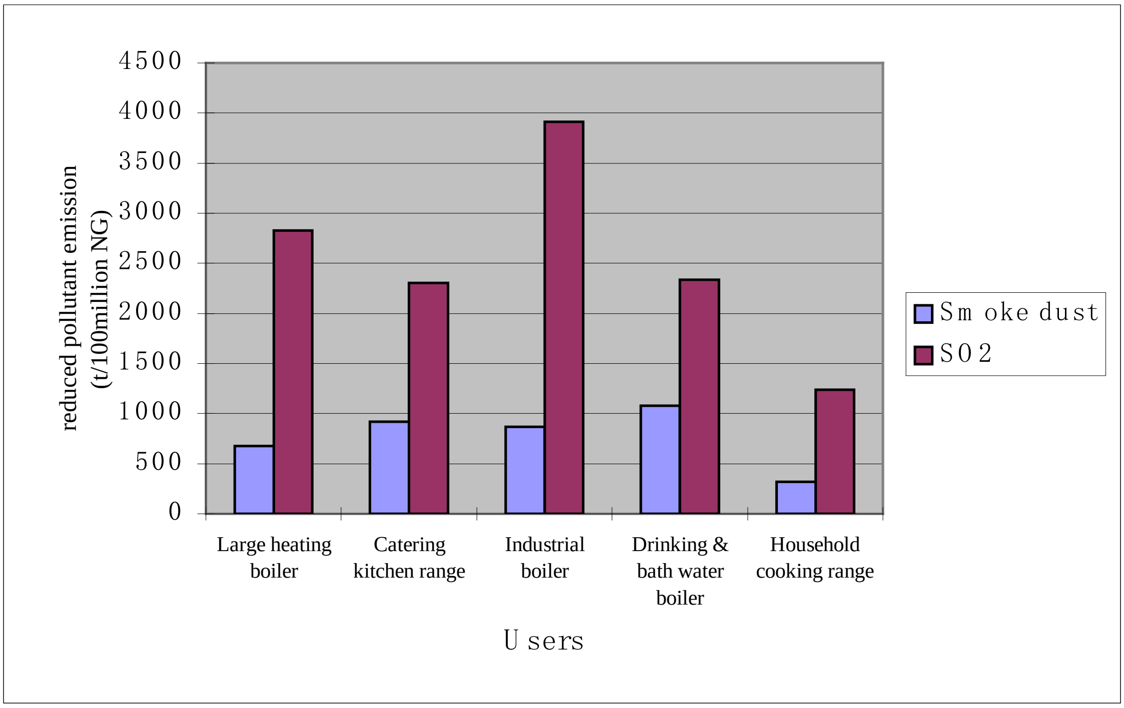
Valuation Study		*Annual Loss (RMB million)*		*Percentage of City's GDP*	*Effects of Pollution*
World Bank study - based valuation. (1997) (1995 Annual Loss in RMB) (With benefit transfer method) (Figures in brackets are 1998 figures multiplied by price index)	Beijing	WTP valuation	7,203 (7,491)	3.7	Mortality; Illness; Restricted activity days; Chronic bronchitis; Other health effects
		Human capital valuation	2,510 (2,610)	1.3	
	Chongqing	WTP valuation	3,347 (3,480)	2.4	
		Human capital valuation	1,166 (1,213)	0.8	
Calculation based on model by Ostro B. (1994, 1996). (1998 Annual loss in RMB) (With benefit transfer method) (WTP and adjusted COI-Cost of Illness)	Beijing	Low value	18,200	9.0	Health damage caused by PM-10 and SO_2
		Central value	75,400	37.4	
		High value	223,000	110.9	
	Chongqing	Low value	5,030	3.5	
		Central value	21,100	14.8	
		High value	65,900	46.1	
Calculated based on model by Rowe et al. (1995) (1998 Annual Loss in RMB) (With benefit transfer method) (WTP and adjusted COI)	Beijing	Low value	6,070	2.9	Health damage caused by PM-10
		Central value	21,100	10.2	
		High value	60,100	29.1	
	Chongqing	Low value	856	0.6	
		Central value	2,940	2.1	
		High value	8,430	5.9	
Calculation done by Beijing Academy of Environmental Sciences et al. (1998) (1995 Annual Loss in RMB) (Figures in brackets are 1998 figures multiplied by price index)	Beijing	Human health	680 (707)	0.3	Health damage caused by TSP and SO_2
		Other losses	2,268 (2,359)	1.2	
		Total	2,948 (3,066)	1.5	
Calculation done by Chang Y. et al.(1996) (1993 Annual Loss in RMB) (Figures in brackets are 1998 figures multiplied by price index)	Chongqing	Human health losses	524 (762)	0.5	No specific pollutants.
		Other losses	1241 (1,806)	1.3	
		Total	1765 (2,568)	1.8	

Note: For details of the valuation process, please refer to the Research Report: Mao X. et al. 2000

2.0 WHY USE NATURAL GAS?

2.1 Natural Gas as a Clean Fuel

Natural gas is a high quality energy source; it is very efficient and has low pollutant content and emissions. When consumers substitute natural gas for coal, emissions of smoke-dusk, SO_2, NO_X and CO fall dramatically (Figure 3).



Source: Beijing Academy of Environmental Sciences et al. (1998)

Figure 3. Pollutant Emission Reduction Effect of Substituting Natural Gas for Coal

Given the low proportion of natural gas and the high proportion of coal in China's energy reserves, using natural gas as fuel has always raised controversy mainly on two issues: (1) that natural gas should be used as a raw material for the chemical industry; and (2) that clean coal technology is the most cost-effective method of improving air quality. These issues are examined below.

2.2 Clean Fuel Versus Chemical Industry Raw Material

Natural gas is not only a high-quality fuel, but also a useful raw material for the chemical industry. According to statistical data, 84% of the world's synthetic ammonia and 90% of the world's methanol are produced from natural gas. Internationally, natural gas has been used much less as a raw material than as a residential fuel. Statistical data sources worldwide indicate that natural gas is used as a raw material less than 10% of the time, while more than 90% of it is used for fuel (Xiao J., 1997).

Historically, in China, natural gas has been used primarily as a raw material, except in the areas with the highest natural gas reserves. Until 1997, two-thirds of natural gas resources was consumed by the industrial sector, and half of this (i.e. one third of the total) was for raw material purposes. In the 1990s, natural gas consumption growth in the chemical industry was around 5%, which was 2% higher than residential natural gas consumption growth. Most of that increased consumption went to the chemical fertilizer industry, which was given high priority in terms of natural gas allocation by the Government's planning department (Wang Q., 1998).

However, some recent studies give different points of view on this issue; these are elaborated on below.

Energy Substitution Effect

Song (1999) argues that the optimal order of priority for natural gas consumption in China is first as residential fuel, then as a chemical industry raw material, and finally as thermal power plant fuel, according to the coal savings that would result from substituting 100 million m^3 of natural gas for coal (Table 4).

Table 4. Coal Saved by Using 100 million m^3 of Natural Gas

Usage		*Coal replaced 10^4t*	*Coal saving 10^4t*	*Coal saving ratio %*
Civilian use (residential)		35 ~53	17 ~ 35	50 ~ 66
Chemical industry raw material		28 ~ 32	10 ~ 14	36 ~ 44
Industrial fuel	Middle and small boilers	22 ~ 25	4 ~ 10	18 ~ 28
	Other stove and furnace	22 ~ 29	4 ~ 11	18 ~ 38
	Puddling coke substitution	28	10	36

Source: Song W. (1999)

Energy saving is also regarded as the first criteria by Jiang (1993) for natural gas utilization selection, i.e. allocating natural gas resources according to energy efficiency. Energy consumption of natural gas and coal in three different applications are compared in Table 5. The conclusion is similar to Song's (1999) study: natural gas as a residential fuel should have the highest priority.

Table 5. Energy Consumption Comparison between Natural Gas and Coal

<table>
<tr><td rowspan="3">Application</td><td rowspan="3">Unit</td><td colspan="2">Natural gas</td><td colspan="3">Coal</td><td rowspan="3">Data source</td></tr>
<tr><td rowspan="2">Volume (m^3)</td><td rowspan="2">Energy consumption (kJ)</td><td colspan="2">Volume (kg)</td><td>Energy consumption</td></tr>
<tr><td>Raw coal</td><td>Standard coal</td><td>kJ</td></tr>
<tr><td>Ammonia synthesizing</td><td>per kg
Relative value</td><td>1.053
100</td><td>40,994
100</td><td>1.880
179</td><td>1.343
128</td><td>39,307
96</td><td>(1)</td></tr>
<tr><td>Power generation</td><td>per kWh
Relative value</td><td>0.18
100</td><td>7,007
100</td><td>0.43
239</td><td>0.31
172</td><td>8,990
128</td><td>(2)</td></tr>
<tr><td>Civil fuel</td><td>per kWh
Relative value</td><td>1.0
100</td><td>38,931
100</td><td>3.0
300</td><td>2.143
214</td><td>62,724
161</td><td>(3)</td></tr>
</table>

Note: According to Literature 1, the energy value of natural gas is 38,931 kJ/m^3, the raw coal unit energy value is 20,908kJ/kg, and the conversion ratio of raw coal to standard coal is 0.7143kg/kg.

Literature 1: Traffic and Industrial Department, National Statistical Bureau, Energy Statistical Year Book, 1991, China Statistical Press.

Literature 2: Huang Qiang, Shell Natural Gas Information and Technology Introduction, Petroleum and Natural Gas Chemical Industry, 1993,2.

Literature 3: Chinese Society of Petroleum, Suggestion from Scientists and Technician, 1992,10,10.

Elasticity of Production Costs to Raw Material Prices

The Designing Institute of the former Chemical Industrial Ministry (Wang Q., 1998) examined the influence of raw material prices on the production costs of synthetic ammonia and urea (Table 6).

Residual oil and water coal slurry can be used in place of natural gas as raw materials in the production of synthetic ammonia and urea. Table 6 indicates that synthetic ammonia and urea production costs are more sensitive to natural gas prices than water coal slurry prices, but about the same as residual oil prices. Over the past few decades, the Government has subsidized natural gas as a raw material. Once this subsidy is removed, natural gas will lose its price advantage over other raw materials.

Table 6. Effect of Raw Material Prices on Production Costs of Synthetic Ammonia and Urea.

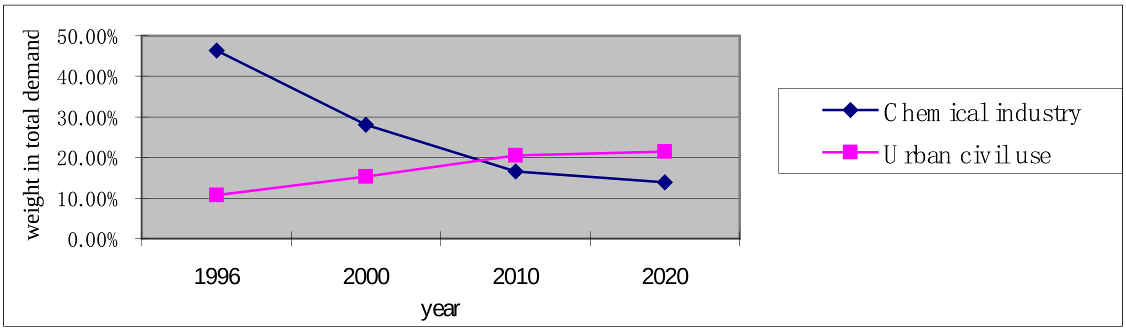
Material price / *Production cost*		*Natural gas RMB/m³*			*Residual oil RMB/t*			*Water coal slurry RMB/t*		
		0.5	0.8	0.9	600	900	1000	100	200	300
Synthetic ammonia	Production costs	780	1,100	1,210	1,070	1,430	1,550	920	1,060	1,200
	Cost elasticity		0.68	0.8		0.67	0.76		0.15	0.26
Urea	Production costs	710	900	960	880	1,090	1,160	790	870	950
	Cost elasticity		0.45	0.53		0.48	0.58		0.10	0.18

Source: Wang Q. (1998)

Use of Natural Gas as a Raw Material Expected to Decrease in the Coming Decades

According to recent research on the future of China's natural gas production and allocation, the use of natural gas over the next few decades is expected to increase as a civilian fuel, but decline as a raw material for the chemical industry (Wang Q., 1998; Qu S., 1999).

Qu S. (1999) predicted that the increase in the rate of natural gas production and supply will exceed chemical industry demand growth for natural gas and moreover, that natural gas consumption of urban residential users will exceed that of chemical industry users (Figure 4).



Source: Qu S. (1999)

Figure 4. Predicted Weight of Natural Gas Demand as Raw Material vs Urban Residential Use

2.3 Natural Gas versus Clean Coal Technology

Clean coal technology is a general term for a range of technologies aimed at reducing coal's pollutant emissions and improving its energy efficiency. The basic framework of China's clean coal technology includes processing (coal washing, coal briquettes and coal slurry), burning (fluidized bed combustion process, powdered coal burning and combined-cycle turbine), transforming (gasification and liquefaction), pollution control technology (flue gas desulfurization) and the comprehensive utilization of coal powder (Fan W., 1998).

Generally, clean coal technology is superior to natural gas substitution in terms of pollutant emission reduction per unit of money spent. However, this does not mean that natural gas substitution should be ignored as a way of reducing pollution. There are at least two reasons for this.

First, some highly efficient scrubbing technologies, such as flue gas desulfurization and fluidized bed combustion, can be applied only by large coal consumers, such as thermal power plants. Small and scattered coal users, such as household and small-scale boilers, can apply only a few clean coal technologies, such as coal briquettes and low sulfur coal substitution. These non-point sources contribute to most of the low altitude SO_2 emissions in urban zones because they have a much lower dispersion rate than do large point sources with high chimneys (in Chongqing, for example, the contribution rate is 70-80%; Figure 5). Furthermore, the pollutant reduction rate achieved by available clean coal technology is far from satisfactory, while natural gas has an almost zero pollutant emission rate (Figure 6). Therefore, substituting natural gas for coal in households and small-scale boilers would have a lower marginal pollutant reduction cost and higher environmental benefit than it would for large-point polluters.

Second, the administrative and monitoring costs associated with implementing clean coal technology are high. Furthermore, it is impossible to monitor all small coal consumers. If the use of coal is permitted, the probability of coal users using cheaper "dirty coal" instead of expensive "clean coal" is high.

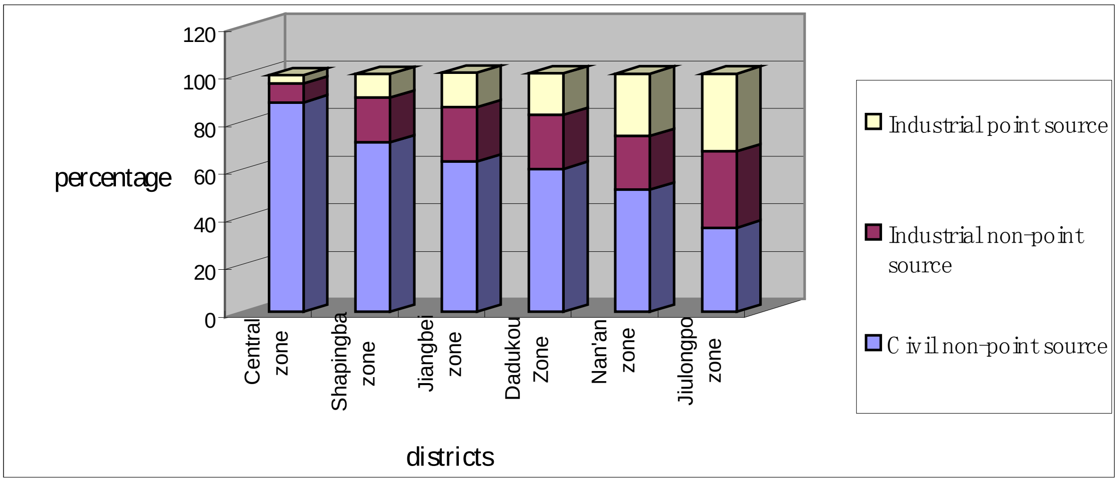
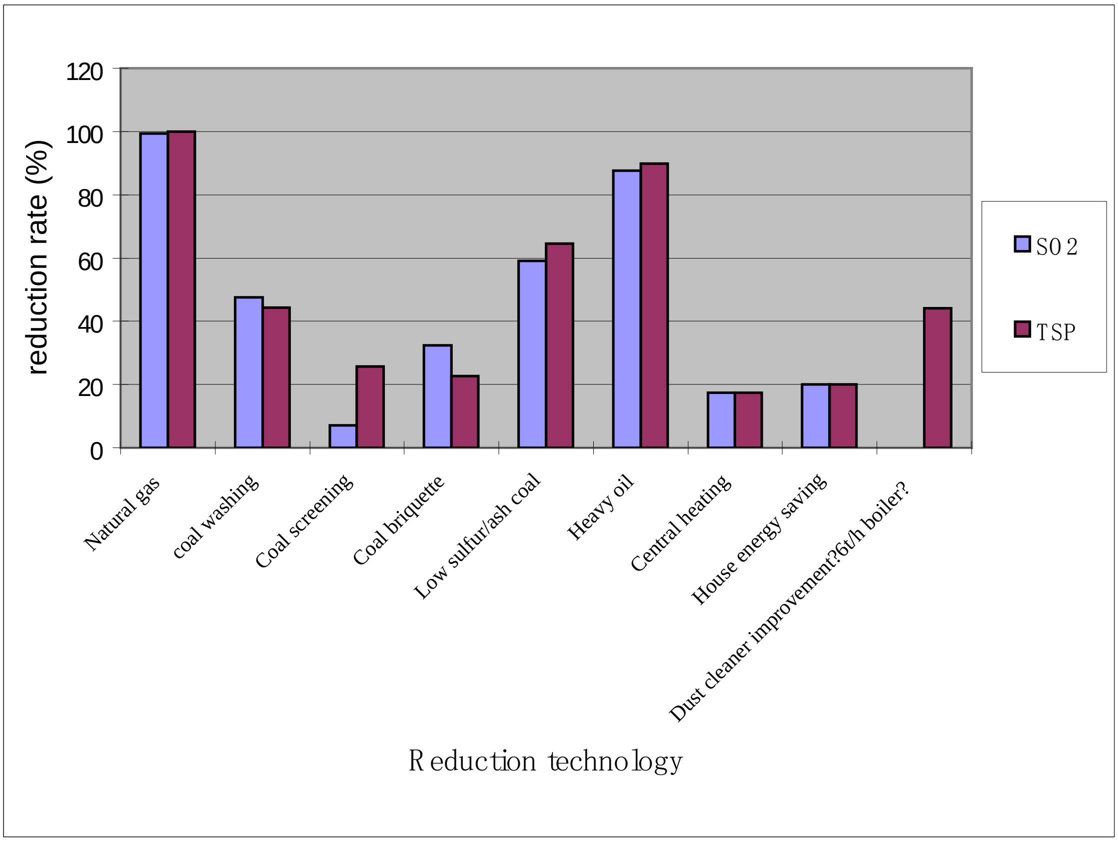


Figure 5. Contribution of Three Types of Sources to Ground SO_2 Concentration in Chongqing Urban Areas



Source: Beijing Academy of Environmental Sciences et al. (1998), Beijing EPB et al. (1998)

Figure 6. Reduction Rate of Some Pollution Reduction Technologies

2.4 Cost-Benefit Analysis Of Urban Natural Gas Substitution: Chongqing and Beijing Case Studies

In order to perform a cost-benefit analysis on the use of natural gas as a substitute for coal, we examined the natural gas substitution projects in Beijing and Chongqing and calculated the net present value (NPV) and internal rate of return (IRR) value under different scenarios.

2.4.1 Chongqing Natural Gas Project

The Chongqing project is an important municipal ambient air environmental protection project sponsored jointly by China's State Environmental Protection Administration (SEPA) and the Japanese Government, (with the support of a soft loan from Japan). The project consists of substituting natural gas for coal in 1,153 boilers with a water evaporation capacity of under 10 tonnes/hour, 18,500 catering cooking ranges and 1,500 drinking water boilers (Chongqing Gas Corporation Ltd. et al., 1998). The estimated pollution reduction effects are shown in Table 7.

Table 7. Air Pollutant Reduction Effects of Chongqing Natural Gas Substitution Project

Pollutant	National air quality 2nd class standard mg/m^3	WHO standard (mg/m^3)	Concentration before the project* mg/m^3	Pollution concentration reduction mg/m^3	Reduction rate	Pollution concentration after the project mg/m^3
SO_2	0.060	0.050	0.183	0.149	81.4%	0.034
TSP	0.200		0.234	0.082	35.0%	0.152
PM_{10}**		0.070	0.140	0.049	35.0%	0.091

* 1998 pollution concentration in Chongqing urban areas

** Conversion coefficient between PM_{10} and TSP used here is 0.6

In the project, dose-reaction function models (Ostro B., 1994, 1996; Rowe et al., 1995) and the benefit transfer method (Orbeta E. M., 2000; Zhang S. et al., 1999) are used to calculate the monetary benefit derived from the reduction in air pollution. The results are shown in Table 8. Pipeline system costs for the project are shown in Table 9, while the results of the cost-benefit analysis are shown in Table 10.

Table 8. Estimated Monetary Benefit of Environmental Quality Improvement from Chongqing Natural Gas Project (1998, RMB billion)

Benefit	*Low value*	*Central value*	*High value*
Monetary benefit of SO_2	.618	2.87	13.1

reduction			
Monetary benefit of PM_{10} reduction	.600	2.06	5.92
Total benefit	1.22	4.93	19.0

Table 9. Pipeline System Costs Of Chongqing Natural Gas Project (10,000 RMB)

Year	*Items*			
	Fixed capital investment	*Circulating fund*	*Operation cost (including NG purchase cost of NG corporation)*	*Cash outflow*
1	5,896.66			5,896.66
2	23,991.04	461.27	15,282.03	39,734.34
3	32,770.31	602.55	35,015.49	68,388.35
4	4,245.51	593.95	54,592.63	59,432.09
5	3,363.89	600.31	72,454.54	76,418.74
6		600.23	72,454.54	73,054.77
7		600.31	72,454.54	73,054.85
8-20			72,454.54	72,454.54

Table 10. Cost-Benefit Analysis Indicators for Chongqing Natural Gas Project

(In 10,000 RMB, Discount rate = 12%, Discount period =20 years)

Cost-benefit Analysis Indicators	*Low value*	*Central value*	*High value*
NPV (Net Present Value)	222,554.16	1,864,952.33	8,100,908.98
IRR (Internal Rate of Return)	26.38%	74.68%	143.03%

Even at low value, the Chongqing natural gas project has satisfactory NPV and IRR values.

2.4.2 Beijing Natural Gas Project

Tables 11-15 show the results for a 1 billion m^3 natural gas substitution project in Beijing.

Table 11. Pollutant Emission Reduction from 1 billion m^3 Natural Gas Substitution in Beijing

Burning facility	*Natural gas allocation 1 billion m^3/yr*	*Coal replaced 10,000tonne/yr*	*Reduced emission 10,000tonne/yr*	
			SO_2	*TSP*
Household cooking ranges	0.85	52.02	0.105	0.027

Catering cooking ranges	0.58	19.87	0.134	0.096
Drinking/bath water boilers	0.64	17.96	0.151	0.069
Industrial boilers	5.05	142.53	1.978	0.439
Large heating boilers	2.88	55.78	0.813	0.195
Total	10	288.16	3.18	0.83

Source: Beijing EPB et al. (1998)

Table 12. Pollutant Concentration Reduction from 1 Billion m^3 Natural Gas Substitution in Beijing

Period	*Items*									
	Coal substitution (10,000t)	*Concentration before the project* in mg/m³*			*Pollution concentration reduction in mg/m³ and reduction rate*			*Pollution concentration after the project in mg/m³*		
		SO_2	*TSP*	*PM-10*	*SO_2*	*TSP*	*PM-10*	*SO_2*	*TSP*	*PM-10*
Heating season	163.48	0.252	0.431	0.259	0.021 (8.4%)	0.017 (3.9%)	0.010 (3.9%)	0.231	0.414	0.248
Non-heating season	124.68	0.042	0.348	0.209	0.012 (28.6%)	0.013 (3.7%)	0.008 (3.7%)	0.03	0.335	0.201

* Concentration in Beijing in 1998.

Table 13. Monetary Benefit from 1 billion m^3 Natural Gas Substitution in Beijing (in RMB billion)

	Low value	*Central value*	*High value*
Monetary benefit of SO_2 reduction	0.340	1.20	3.30
Monetary benefit of PM_{10} reduction	0.204	0.950	4.33
Total benefit	0.544	2.15	7.63

The construction costs of the Shan-Jing long-distance natural gas transportation line were very high. In 1997, the estimated total investment was RMB 3.935 billion. Of this, fixed capital costs amounted to RMB 3.509 billion. (Table 14 provides a breakdown.)

Table 14. Breakdown of Fixed Capital Costs for Shan-Jing Natural Gas Pipeline Project (10,000 RMB)

Items	*Equipment purchase*	*Architecture engineer*	*Equipment engineer*	*Other*	*Total investment*	*Proportion of total investment (%)*	*Proportion of engineer cost (%)*
Engineer cost	30,222	52,147	172,334	1,493	256,196	73.01	100
Pipe material					93,369	26.61	36.44

Pipeline equipment engineer					99,404	28.33	38.80
Station-field engineer					24,970	7.12	9.75
Large penetration and bridge engineer					5,443	1.55	2.12
Communi-cation engineer					8,388	2.39	3.27
Automatic control engineer					2,500	0.71	0.98
Dispatching center engineer					17,157	4.89	6.70
Base engineer					4,965	1.41	1.94
Other cost				59,749	59,749	17.03	23.32
Preparation budget				34,960	34,960	9.96	13.65
Total fixed capital	30,222	52,147	172,334	96,202	350,905	100	136.97
Ratio (%)	8.61	14.86	49.11	27.42	100		

Source: Yang J. (1998)

Urban allocation pipeline system costs are also high. The Beijing Natural Gas Corporation controls up to 1,200km of urban natural gas distribution pipeline. Its total fixed assets amount to RMB 0.8 billion (Beijing Academy of Environmental Sciences et al., 1998). It is assumed here that the entire amount is the expenditure for the urban allocation system construction.

Operation and maintenance costs are assumed to be 30% of the gateway price of natural gas (Beijing Academy of Environmental Sciences et al., 1998); in the one billion m^3 substitution scenario, this works out to RMB 297 million per year.

Table 15 shows that the IRR and NPV are unsatisfactory in the case where the estimated environmental benefit is low. Two factors explain this. The first is the large investment in pipeline construction: in the one billion m^3 scenario, economies of scale have not been achieved. As the quantity of natural gas transported increases, NPV and IRR also tend to increase. The second reason is that the allocation of natural gas has not been optimized, which means that the assumed allocation scenario does not conform to the marginal cost minimization rule.

Table 15. Cost-Benefit Analysis Indicators for Beijing Natural Gas Project

(10,000 RMB, Discount rate = 12%, Discount period =20 years)

Cost-Benefit Analysis Indicators		*Low value*	*Central value*	*High value*
1 billion m^3 scenario	NPV	-240,566.95	687,603.51	3,854,710.65
	IRR	3.0%	29.4%	80.6%
3 billion m^3 scenario	NPV	-54,736.55	2,729,774.81	12,231,096.25
	IRR	10.9%	49.7%	126.3%

In general, substituting natural gas for coal, especially non-point users, makes the most sense from a cost-benefit point of view in large cities with dense population and intensive economic activity.

3.0 SUPPLY AND DEMAND OF NATURAL GAS

3.1 Natural Gas Resources

Although coal and petroleum dominate China's energy structure, there are significant natural gas resources in the country. According to the data released by the Chinese Government (1993), China holds 38 trillion m^3 of natural gas, and the exploitable reserve is 10.5 trillion m^3. Given the country's large resources of coal and oil, many Chinese geologists believe that natural gas reserves far exceed the published estimate. Complicated geology, remote locations and incomplete surveys have made it difficult to identify and develop gas reserves in China. Perhaps more importantly, there have been few incentives to find and develop new gas fields (Logan and Luo, 1999).

China has announced plans to build a liquefied natural gas (LNG) import facility in Guangdong. There is currently a global oversupply of LNG because new supply facilities have become available while demand from Japan and Korea has fallen due to an economic slowdown. Capital costs to build new LNG supply trains have fallen by as much as 40% this decade (Sandison, 1999). China is considering the construction of additional LNG terminals in Fujian and Shanghai. Furthermore, some of the world's richest gas fields lie less than 3,000 km from Beijing in Siberia, near Irkutsk. Gas from these fields would be China's cheapest import option. Discussions are also underway for pipeline gas imports from Sakhalin and Kazakhstan (in Middle Asia) (Logan and Luo, 1999).

3.2 Natural Gas Demand

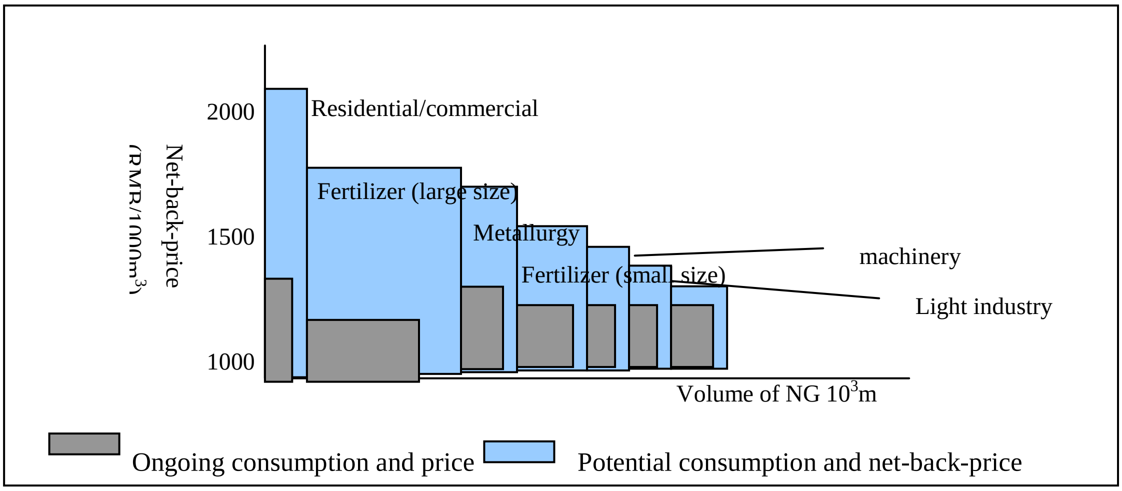
3.2.1 Net-Back Price of Natural Gas

Figure 7 shows the estimated net-back price of natural gas for different uses in China (Makholm, J. D. et al., 1995). The net-back price is basically the price of the cheapest substitute for natural gas, adjusted by factors such as efficiency and cost of switching from natural gas to the substitute or vice versa. The rationale for using net-back prices lies in the assumption that consumers always choose the cheapest substitute. The net-back price therefore gives a better approximation of the real demand curve for natural gas (Figure 7).

It can also be seen from Figure 7 that natural gas prices are too low and do not reflect real demand. This can lead to a shortfall in natural gas supply due to insufficient financial incentive for natural gas exploration and exploitation. In the chemical fertilizer industry, natural gas is excessively subsidized, resulting in artificially low natural gas prices and potentially leading to wastage and inefficient use.

3.2.2 Need for Improvement in the Use of Natural Gas in Chinese Cities

Insufficient terminal demand in the natural gas market has meant that sales have been disappointing for producers. From 1991 to 1997, new natural gas reserves amounted to 100 billion m^3, which is 1.4 times the total of the previous 40 years (Wang et al., 1998; State Bureau of Statistics, 1998). From 1991-1995, the annual rate of newly discovered natural gas reserves reached 11%, while natural gas production and consumption increased by only 2% annually. Average natural gas consumption in China is also low compared with that of other countries (Figure 8).



(Source: Makholm J. D. et al., 1995)

Figure 7. Net-Back-Price-Based Demand Curve for Natural Gas

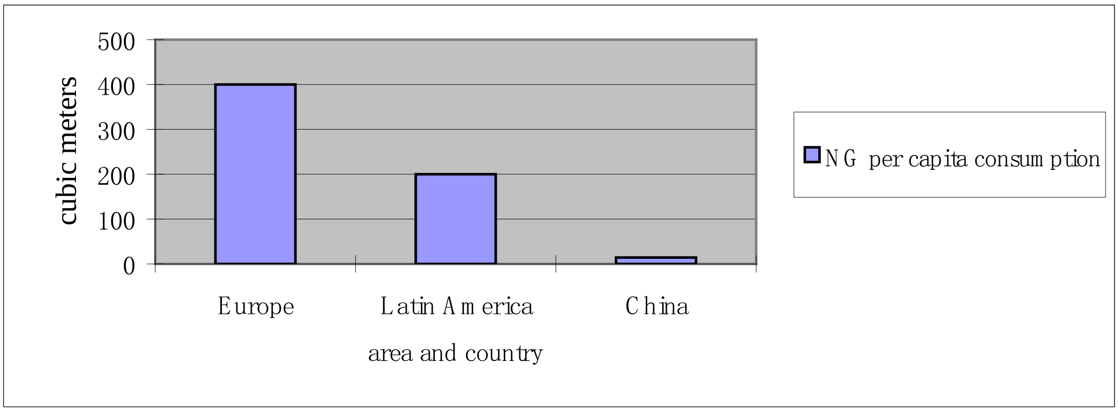


Figure 8. Natural Gas Per Capita Consumption in Selected Places (1997)

3.2.3 Terminal Natural Gas Consumers in Cities

To examine the financial burden of using natural gas from the point of view of consumers, we calculated the increased cost to consumers who substitute natural gas for coal. We considered three cost aspects: fuel prices, equipment expenditure and operational costs.

First of all, natural gas substitution means higher fuel costs, as it is considerably more expensive than coal in terms of price per unit of thermal value, as shown in Table 16.

Substituting natural gas for coal also requires a large capital expenditure, as consumers need to either convert their old coal boiler into a natural gas boiler, or replace their old equipment.

Table 16. Price of Natural Gas and Coal in Beijing

Fuel	*Unit*		
	Caloric capacity	*Price per kg or m^3*	*Price per 1,000kcal**
Shanxi Coal	6,200 kcal/kg	RMB 0.22 /kg	RMB 0.04 / 1,000kcal
Shanganning Natural gas	8,480 kcal/m^3	RMB 1.40 /m^3 RMB 1.80 /m^3	RMB 0.17 /1,000kcal RMB 0.212 / 1,000kcal

* Converted to the same thermal unit.

Table 17 estimates the additional financial burden for different types of consumers, based on the one billion m^3 allocation scenario with reference to the research report published by the Beijing Academy of Environmental Sciences et al. (1998).

Table 17. Annual Incremental Costs for Different Users in the 1 billion m^3 Natural Gas Project (10,000 RMB/year)

No.	*Users*		*Household cooking ranges*	*Catering kitchen ranges*	*Drinking & bath water boilers*	*Indus-trial boilers*	*Large heating boilers*
1	Equipment fee (Occurs only in the first year)		536	139	309	806	611
2	Fuel cost	Coal fuel fee	16,963	2,423	3,966	32,690	12,271
		Natural gas fee	11,861	10,430	11,590	90,974	51,756
		Cost difference between natural gas and coal	5,102	8,007	7,624	58,284	39,485
3	Other saving of facility					460	156
4	Saving of land occupation					354	134
5	Saving of electricity					867	261
6	Saving to water fee						34
7	Saving to labour force						110
8	Saving of ash-slag removal		483	69	113	929	349
9	Pollutant treatment reduction		560	173	230	2,744	1,020
10	Annual cost (3)+(4)+(5)+(6)+(7)+(8)+(9)-(2)		6,144	-7,487	-6,663	-52,999	-36,894

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

A negative sign means increased costs.

Coal is much cheaper than gas, so most users would pay much more after switching to natural gas. Table 18, however, shows that for commercial and residential consumers, money spent on natural gas only amounts to a small proportion of their total annual budgeted cost, indicating that there is much potential for commercial and residential consumers to expand their total consumption of natural gas.

Table 18. 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: Makholm J. D. et al. (1995)

3.2.4 Initial Installation Fee and Gas Source Fee

Consumers in Chongqing and Beijing must pay an initial installation fee (IIF) and gas source fee (GSF), respectively, to local distribution companies before they can gain access to natural gas. The initial aim of the surcharge was to accumulate capital funds for natural gas infrastructure construction and development. It originated during China's transitional phase in moving from being a traditionally planned economy to a market economy, but the surcharge is becoming a significant obstacle to natural gas deployment (Table 19).

Table 19. Gas Source Fee for Different Consumers in Beijing

	Consumer type		
	Households	*Drinking & bath water boilers and public kitchen ranges*	*Industrial boilers*
Charging standard	RMB 2,300-2,400 per household	RMB 1,200 per cubic metre of daily gas consumption	RMB 704,000 per evaporation tonne (or 0.7 MW).

In the case study, the GSF amounted to 70-80% of total consumer costs in the first year of switching from coal to natural gas. The economic effects of the IIF/GSF are shown in Figure 9.

Supply curve S_1 represents the current situation; the point at which it intersects with the demand curve indicates the partial equilibrium point Q_0. If the

IIF/GSF were removed, the lower supply curve S_2 would apply and the quantity of gas demanded would increase due to the lower market equilibrium price. Note that the vertical distance between the two supply curves depends on how the IIF/GSF is administered. If it is a one-off charge, as it is in Beijing and Chongqing, the full amount is reflected in the difference between the supply curves. If it annualized, the impact is much less significant.

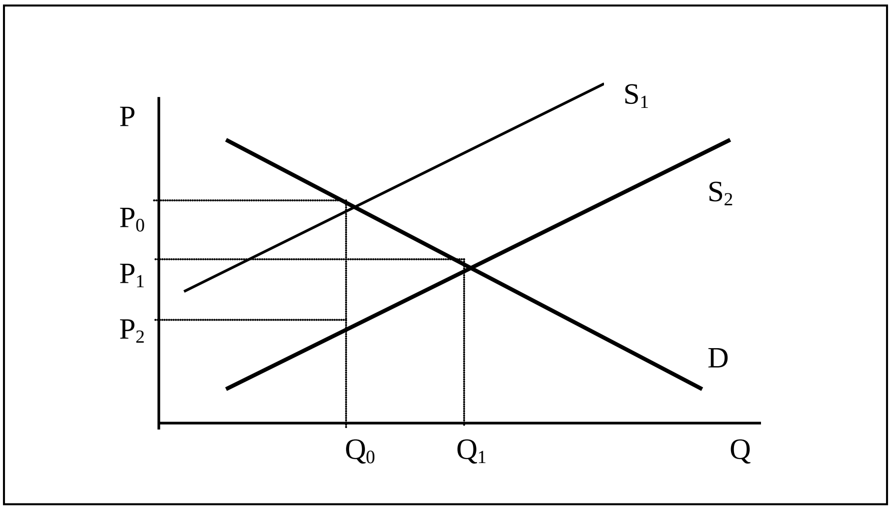


Figure 9. Economic Effects of IIF/GSF

For residential consumers who expect income growth but who have difficulty in paying a one-off charge, the IIF/GSF sets a high access threshold. For other potential commercial and small-scale industrial boiler consumers, the fee makes the use of natural gas less attractive.

3.2.5 High Cost of Urban Natural Gas Pipeline System Construction

Upstream natural gas exploration, exploitation and long-distance pipeline system construction projects fall under "industrial construction projects" management in the national economic plan. Downstream urban distribution system construction is regarded as urban civic infrastructure construction projects. Upstream and downstream infrastructure construction projects therefore fall into two separate planning systems and it is difficult to harmonize the two.

The lack of city terminal distribution systems may still hinder terminal consumption even when there is a high-pressure pipeline. As terminal distribution construction is capital-intensive, the use of foreign and private funds could be a solution to the problem of the lack of capital resources.

3.3 Supply Surplus

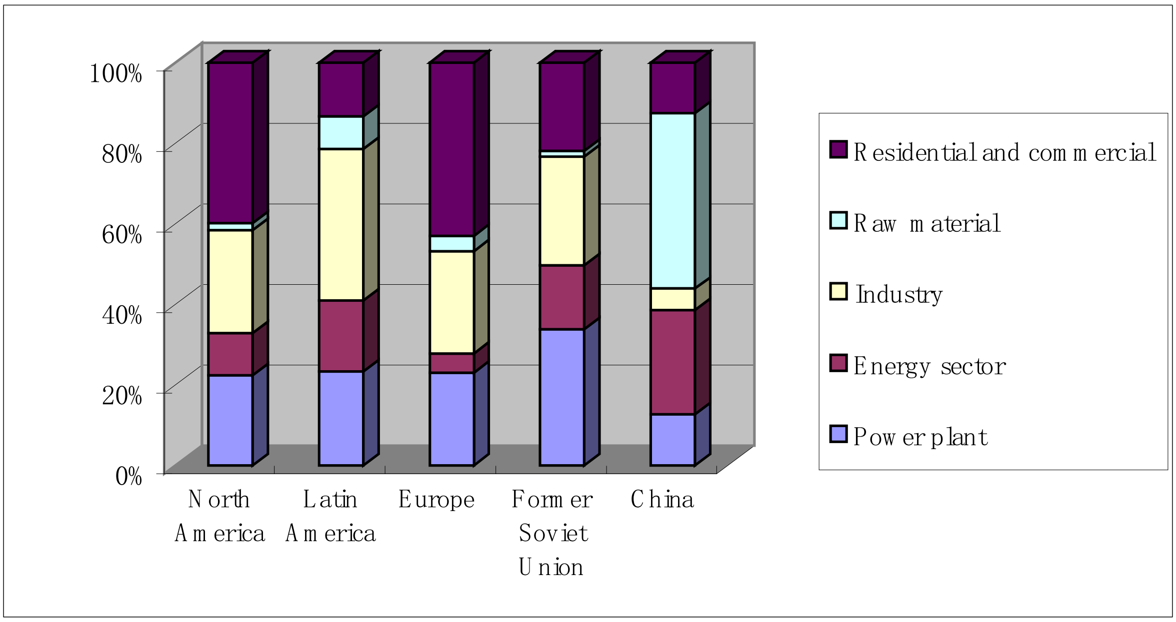
On the demand side, there has been both an urban natural gas shortage and a lack of demand. The supply side, however, has experienced a surplus of natural gas over the past few years.

3.3.1 Temporary Surplus

From 1997-1999, the financial crisis in Asia affected most of the industries that were using natural gas as a raw material, and this led to sharp decrease in the demand for natural gas. According to the Chongqing Statistical Year Book (1999), natural gas consumption decreased from 3.128 million tonnes (SCE) in 1997 to 2.913 million tonnes (SCE) in 1998.

3.3.2 Structural Surplus

In China's natural gas consumption structure, the use of natural gas as a chemical industrial raw material has always been overweighted (Figure 10). In the biggest natural gas production area, the Sichuan Basin, 60% of the total natural gas terminal consumption goes to chemical fertilizer production, 28% to other industrial sectors, and 12% is residential consumption. Once the chemical fertilizer industry stagnates, however, natural gas consumption will fall sharply.



Source: IEA (1998)

Figure 10. Natural Gas Consumption Structures in Selected Continents/Countries (1997)

3.3.3 Regional Surplus

Most of the natural gas fields lie in the poorer western part of China, far away from the more prosperous eastern areas of China, which means that the natural gas must be transported through long-distance pipelines to reach the largest potential markets; the large cities in the east. However, the lack of high-capacity long-distance pipelines across this vast country makes transportation difficult.

In China, the Sichuan Basin is the only area with rich natural gas resources and a relatively well-developed pipeline transportation system. A high-pressure pipeline has been constructed to transport natural gas from the Changqing natural gas field (in Shanxi Province) to Beijing. The Tarim Basin (in the Xinjiang Autonomous Region) holds an optimal natural gas reserve. An ambitious plan to build a long-distance high-pressure pipeline from the Tarim Basin to Shanghai was announced in 2000. (*Guangming Daily*, 2000), but its construction is still in question given the amount of capital required (Table 20).

Table 20. Pipeline Construction Costs in China

Item	*Pipeline*				
	Shanxi Beijing	*Jingbian Xining*	*Luntai Kuerle*	*Kuerle Shanshan*	*Shanshan -Urumuch i*
Pipe diameter (mm)	660	426	457	610	457
Length (km)	860	489	195	476	308
Total investment (RMB billion)	39.35	7.89	3.29	18.30	5.23
Unit investment (RMB 10,000 /km)	457.56	163.19	168.72	384.45	169.81
Investment per tonne of pipeline (RMB 10,000/t)	3.14	2.53	2.52	3.23	2.53

Source: Yang J. (1998)

3.3.4 Planning Surplus

China's planned economy is the fundamental reason for the natural gas surpluses. Over 90% of natural gas production and allocation is controlled by the Central Government. The Central Government regulates the total natural gas supplied to enterprises, especially important users such as large chemical fertilizer factories and cities. The rigidity and illogicality of Central Government planning has led to a situation in which inefficient consumers with a large quota of natural gas are unable to use up their allocated quotas, while other consumers faced with a shortage of natural gas, are unable to buy more from the market. Producers are required to continue supplying gas to consumers who cannot pay, resulting in huge arrears.

Table 21 shows a comparison of key policy indicators affecting investment in natural gas infrastructures in selected APEC countries.

Table 21. Policies Affecting Investment in Natural Gas Supplies, Infrastructure and Trading Networks in Selected APEC Countries

	Country		
	Canada	*United States*	*China*
Legal	National and provincial laws governing natural gas sector; judicial review of agency decisions; court enforcement of private contracts	Federal and state laws governing natural gas sector; judicial review of regulatory decisions; court enforcement of contracts	
Fiscal	44.62% corporate income tax; variable royalties	35% corporate income tax	33% corporate income tax; variable royalties; capital import taxes
Regulatory	Independent federal/ provincial agencies	Independent federal and state authorities	Central Government authority
Pricing	Market wellhead price	Market wellhead price; regulated transportation and distribution services	Price controls on established production (i.e. below-market natural gas rates)
Production/Sale	Resources owned by provinces	Private production and marketing companies; state regulation of production	Chinese National Petroleum Corporation
Transportation/ Distribution	Private transportation companies; open access to transportation and distribution pipelines	Private transportation companies; private and (some) municipal distribution companies; open-access transportation	
Export/Import	Imports/ exports regulated by National Energy Board	No restriction on LNG imports; exports/imports approved by DOE	

Source: "Recommendations Concerning Accelerating Investment in Natural Gas Supplies, Infrastructure and Trading Networks in the Apec Region." Endorsed by the APEC Energy Ministers at the Third Meeting in Okinawa, Japan on 9 October, 1998.

4.0 POLICY RECOMMENDATIONS

4.1 Policy Preference for Residential Use

Given China's limited natural gas resources, and the monopoly inherent in the natural gas industry (especially in natural gas transportation), governmental regulation is inevitable in the foreseeable future. Governmental allocation should, however, prioritize residential use and surcharges on residential consumers, such as the gas source fees and initial installation fees should be abolished immediately.

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

The natural gas industry has always been strictly controlled by the Central Government and participation by private and foreign companies, prohibited. There has long been a shortage of capital in all sectors of the industry. The level of exploration is insufficient to determine the true potential of natural gas reserves. Transportation departments of state-owned natural gas companies do not have enough funds to renew pipeline, pumping and gas-clearing equipment. Municipalities have insufficient resources to expand their natural gas branch and sub-branch pipeline systems.

An injection of fresh foreign and private capital would be a logical solution to these problems. Some foreign companies have already 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 infrastructure construction; this could take the form of joint ventures and joint-stock companies.

According to the Foreign Merchant Investment Industry Directive Catalog (1997) issued by the State Development Planning Commission (SDPC), State Economic and Trade Commission (SETC), and Ministry of Foreign Trade and Economic Cooperation (MOFTEC), only Chinese companies could act as holding companies in the construction and management of natural gas transportation pipeline projects. The municipal natural gas pipeline system was completely off-limits to foreign investors.

Some changes have been made. On 12 July, 2000, the SDPC declared a change in policy for the west-to-east natural gas transportation project: foreign companies were permitted to join the project as holding companies, and the municipal pipeline-network system would also be opened to foreign investors (*People's Daily*, 2000). Other preferential terms for foreign investors in the project included the elimination of the natural gas prospecting and exploitation fee, tax exemption on imported equipment, and lifting of restrictions in the land requisition policy. This was a start in the right direction.

4.3 Environmental Economic Incentives

As a way of encouraging the use of natural gas as a residential and commercial fuel in large cities, there should be a system of economic penalties and incentives, such as a pollution discharge fee and tradable emission permits. These could be implemented for natural gas and all its substitutes, especially coal.

Such a system should make it disadvantageous to use dirty fuel and advantageous to use clean fuel namely, natural gas. The system should also stimulate and support the effective implementation of cost-effective pollution control measures.

The Government could choose to subsidize municipal residents according to how much environmental benefit they could produce after switching from coal to natural gas. At the same time, the Government should stop subsidizing natural gas for chemical fertilizer production; in fact, it should tax it. There is little incremental pollution from using natural gas substitutes as a raw material for the chemical industry.

All decision-making on natural gas production and allocation should definitely take into consideration the potential environmental damage caused by natural gas substitutes as fuel. From the point of view of environmental conservation, the supply of natural gas should be increased.

More importantly, environmental considerations should change the relative prices of natural gas in different applications.

In September 1999, to promote the replacement of coal with natural gas, the Beijing EPB raised the pollution charge for SO_2 emissions caused by coal burning to RMB 0.50/kg for low-sulfur-content coal and RMB 1.20/kg for high-sulfur-content coal. The charge will now be levied whether the polluter attains the emission content standard or not. For oil and gas, the rate is RMB 0.20/kg.

However, we can see from Table 22 that even with these higher rates, the SO_2 emission charge amounts to only a small fraction of the consumer’s total fuel cost, and does not nearly reflect the environmental damage caused. Only when the charge is high enough will it become a useful tool for encouraging natural gas substitution.

Table 22. SO_2 Emission Charges for Different Users in Beijing

Items		*Consumers*				
		Large heating boiler stations	*Drinking & bathing water boilers*	*Catering kitchen ranges*	*Household cooking ranges*	*Industrial boilers*
Pollution charge for SO_2(RMB/yr.unit)		133,000	392	128.4	2.2	7,003
Fuel cost (RMB/yr)	Coal fuel fee	4,010,000	19,800	7,100	480	222,000
	Natural gas fee	16,940,000	60,100	20,000	490	643,500
Pollution charge as percentage of coal fuel fee		3.32%	1.98%	1.81%	0.46%	3.15%

4.4 Command and Control Instruments

Since the end of 1998, Beijing has issued several regulations related to pollution emissions in urban areas due to the deteriorating air quality. One of the most important has been to designate non-coal areas, in which all coal-burning facilities must switch to natural gas or another clean fuel. Although arbitrary, command and control instruments are an effective and expedient method of helping control the serious air pollution problem. Figure 11 shows the extent to which this method has succeeded in increasing natural gas penetration in Beijing during the past three years.

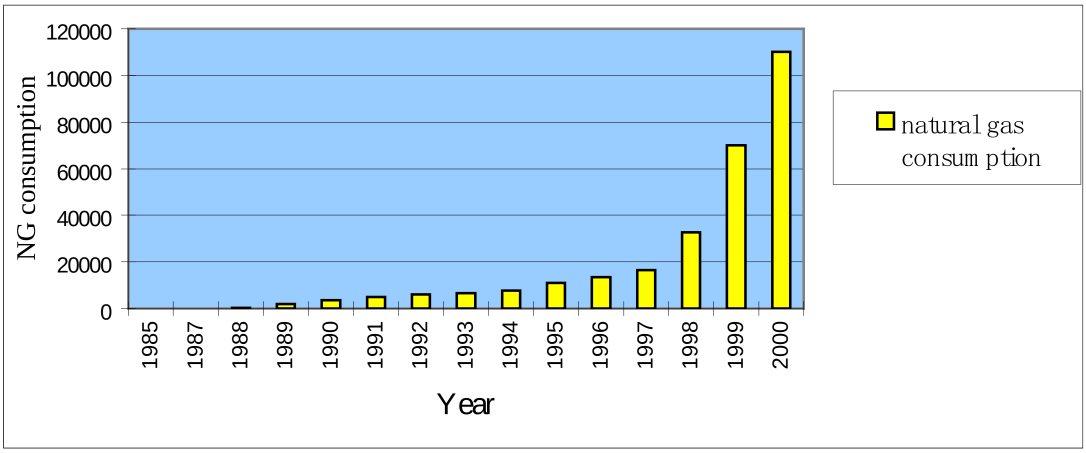
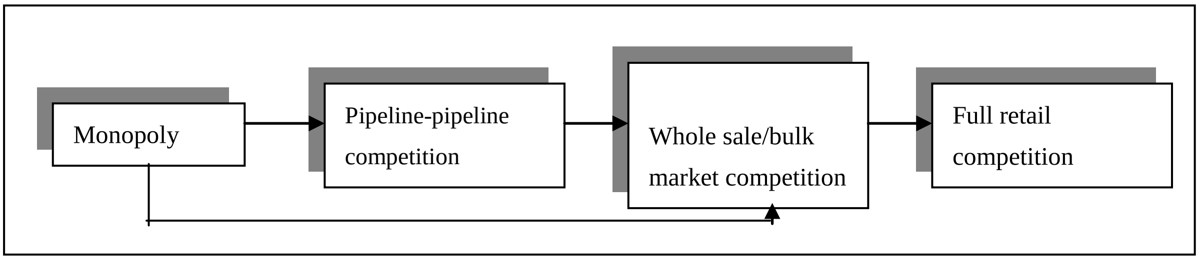


Figure 11. Natural Gas Consumption in Beijing by Year

4.5 Market-Oriented System Reform in the Natural Gas Industry

Since the existing planned system in China's natural gas industry has been one of the main barriers to natural gas penetration, transforming it into a more open and flexible system is essential. Some market economies have gradually undertaken reforms towards this end (Figure 12). Good examples are the United Kingdom, the United States and Canada (IEA, 1998).



Source: IEA (1998)

Figure 12. Stages of Development of Gas-to-Gas Competition

A basic requirement of deregulation and market-oriented reform is that there must be more than one supplier in the (natural gas) market, and that supply and transportation services must be separated, so that consumers can choose the best wellhead and transportation price combination. Since the natural gas transportation system will have a natural monopoly, it must be strictly regulated to prevent abuse. Natural gas pricing also needs to be changed from a Central Government method to a market adjustment method (see Table 23).

The ideal natural gas production-retailing system should be able to avoid monopoly and be efficient. It is essential to change local natural gas distribution from a monopoly enterprise into a competitive system comprising independent entities responsible for running pipeline networks only in city zones and under the supervision of the municipal government. There should be more than one natural gas retailer, and this must be the precondition in order to introduce competition into the natural gas market. Terminal consumers must be able to buy natural gas from their preferred natural gas retailer (Figure 13).

Table 23. Pricing Approaches Under Different Market Structures

	Monopolistic	*Competitive*		
Market structure	Pure monopoly	A. Pipeline-to-pipeline competition only	B. Mandatory third-party access (TPA) 1. Competitive wholesale market (TPA to high-pressure system)	B. Mandatory third-party access (TPA) 2. Full retail competition (TPA to entire system)
Pricing approach	Price discrimination between customers. Net-back market value, cost-plus or mix of both.	Restricted form of discriminatory net-back market value (depending on extent of competition)	Inter-fuel competition and/or gas-to-gas competition (depending on gas supply curve)	Same as for competitive wholesale market
Example	France, Belgium, Netherlands, Spain, Italy	Germany	United States, Canada	Britain

Source: IEA (1998)

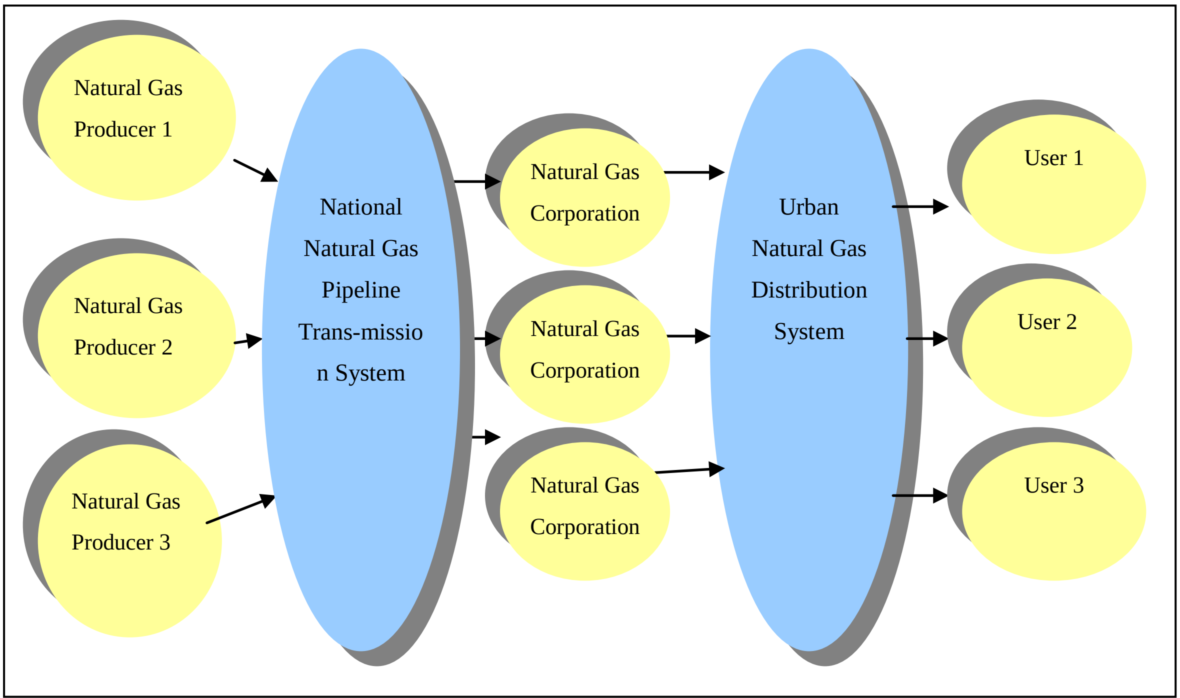


Figure 13. Framework of an Ideal Natural Gas Producing-Retailing System

5.0 SUMMARY

China's large cities have been suffering serious coal-smoke pollution over the past few decades.

After years of changing government policy on the issue of natural gas allocation in China, the declining urban air quality has led to renewed calls for the increased use of natural gas in large cities as a way of reducing coal-smoke pollution emissions. The debate on the rationale for using natural gas as a substitute for very cheap coal in China, however, continues. Even in those cities that want to increase natural gas penetration, there is a wide range of systematic barriers that make it a very difficult task. Responding to the issues and examining the barriers were two major objectives of this research. Beijing, the capital of China, and Chongqing, an important industrial and commercial city in southwest China, were selected as two case study cites.

This report began by reviewing the general air pollution situation in China's large cities. The severe coal-smoke air pollution is largely due to the extremely heavy weighting of coal in China's primary energy structure and the large amount of coal consumed in urban areas. The estimated health damage in Beijing and Chongqing due to SO_2 and PM_{10} emissions are extremely high and indicate the urgency of implementing measures to reduce these emissions.

Natural gas, a clean fuel with negligible SO_2 and dust emission, is also an important raw material for the chemical fertilizer industry in China. For the past few decades, the Government has allocated most of China's available natural gas supply to chemical fertilizer production. This report cites abundant literature that contend that, without government subsidies, natural gas as a chemical fertilizer raw material would lose its economic superiority over other raw materials, and that natural gas consumption will decline as an industrial raw material and increase as a residential fuel over the next few decades.

Clean coal technologies are regarded as the cheapest way of reducing coal-smoke pollution. However, clean coal technologies that can be used by urban non-point source residential consumers are limited, while administrative and monitoring costs are high. Furthermore, SO_2 and PM_{10} emissions from urban non-point sources represent a large proportion of low-level air pollution in urban areas, and it is this that has caused the most health damage. Therefore, substituting natural gas for coal in the case of scattered urban small coal consumers, such as households, catering cooking ranges and small boilers could generate huge environmental health benefits. For large heating boilers and thermal power plants, switching from coal to natural gas is still out of the question at this stage due to the large incremental costs involved and the lower low-level air pollution reduction incentive.

A cost-benefit analysis was carried out on the urban natural gas substitution projects in Beijing and Chongqing and it was concluded that natural gas substitution could be justified in terms of NPV and IRR if environmental health benefits were taken into consideration.

We carefully examined the systematic barriers to natural gas penetration from both the demand and supply perspectives. We argued that, for the past few decades, natural gas in China's planned economy has been under-priced, and this has discouraged natural gas exploration and exploitation. The planned economy has also led to an arbitrary natural gas allocation policy that has favoured the chemical fertilizer industry at the expense of residential consumer needs.

The monopoly of local natural gas distribution companies has enabled them to levy surcharges on residential natural gas users. This, in addition to equipment reconstruction or replacement costs and the price gap between relatively expensive natural gas and very cheap coal, has made the switch from coal to natural gas costly for most consumers. A detailed economic analysis of different consumers has revealed this as the reason why the natural gas option has not been embraced by many in the residential market. This is an ironic situation as residential and commercial demand for natural gas is, in fact, high.

A domestic capital shortage is also holding back the expansion of high-pressure pipelines and urban distribution pipeline network construction, indicating the need for foreign capital.

To eliminate the existing systematic barriers to increased natural gas penetration, we make the following policy recommendations:

- Given China's limited natural gas resources and the inherent monopolistic structure of the natural gas industry, Government intervention namely, by way of regulation, is imperative to successfully achieve increased natural gas usage in the foreseeable future. Governmental allocation should prioritize municipal use and surcharges levied on municipal consumers for the use of natural gas should be abolished immediately.

- Effective environmental economic policy instruments should be implemented. The current pollution charges levied against urban coal consumers emitting SO_2 and TSP have failed to discourage coal burning due to their minimal punitive effect. It is therefore necessary to raise the pollution charges on dirty fuels such as coal and to subsidize clean fuel consumption.

- Command and control instruments should also be used to quickly and effectively promote the use of natural gas. Beijing has significantly improved its ambient air quality over the past two years with the designation of non-coal regions in an attempt to win its bid for the 2008 Olympic Games.

- In its transformation from a strict planned economy to a market economy, China should implement a long-term market-oriented system reform in the natural gas production and retailing structure.

- The inadequacy of the municipal natural gas terminal distribution infrastructure is one of the main obstacles. Foreign and private capital should be encouraged into the existing state-controlled natural gas production, transportation and municipal distribution infrastructures to resolve the capital shortage problem faced by most Chinese cities.

REFERENCES

Beijing Academy of Environmental Sciences, et al., 1998,5. Compounding Environmental Protection Policy Study for Developing Gas Fuel in Beijing. Research Report.

Beijing EPB et al., 1998. Beijing Urban Energy Structure Reconstruction and Countermeasure Study. Research Report.

Chang, Y.G and T. Hu. 1996, The Evaluation of Economic Damage from Atmospheric Pollution in Chongqing, in T.Hu and H.D.Wang (ed), Environmental Economics in China – From Theory to Practice. Chinese Agriculture Science Press. Beijing.

Chen, H.P. 1999. Probing Into Energy Policy Oriented to Sustainable Development in China. Energy Engineer Journal, 2, 1-4.

Chongqing Gas Corporation Ltd., et al. 1998. Project Proposal for Chongqing Urban Small-Medium Boilers and Cooking Range Reconstruction. Chongqing.

Chongqing Statistical Bureau. 1999. Chongqing Statistical Year Book - New Chongqing 50 Years. China Statistical Press. Beijing.

Fan, W.T. 1998. World Coal Industry Situation and Development Perspective. Chinese Energy Journal, 9, 1-5, 19.

Guangming Daily. April 3, 2000.

IEA (International Energy Agency). 1998. Natural Gas Pricing in Competitive Markets. IEA Research Report.

Jiang, S. 1993. Discussion on Natural Gas Utilization. Petroleum and Natural Gas Chemical Industry Journal, 22(4), 37-42.

Logan, J. and D.K. Luo. 1999. Natural Gas and China's Environment. IEA-CHINA Conference on Natural Gas Industry. November 9-10. Beijing.

Makholm, J.D. et al. 1995. Allocation and Pricing of Natural Gas in Sichuan. National Economic Research Association (NERA) Research Report. Chongqing University Press Inc. Chongqing.

Orbeta, E.M.; C.M. Rufo, Jr.; and A.L. Indab. 2000. Benefit and Costs of Controlling Emissions from Fossil-fired Power Plants: Region IV, Philippines. EEPSEA Research Report.

Ostra, B. 1994. Air Pollution and Mortality: Results from Santiago, Chile. World Bank, Washington D.C.

______ 1996. A Methodology for Estimating air Pollution Health Effects. World Health Organization. Geneva.

People's Daily. July 14, 2000.

Qu, S. 1999. Natural Gas Development Situation and Perspective. Energy Study Institute. SDPC (State Development Planning Committee). Beijing. Research Report.

Rowe, R.D.; C.M. Lang; L.G. Chestnut; et al. 1995. New York State Environmental Externalities Cost Study. Oceana Publications. Dobbs Ferry. New York.

Sandison, G. 1999. Overview of Economics of the LNG Project Chain. Presented at the 2nd Sino-US Oil and Gas Industry Forum. July 21. Houston. Texas.

SEPA (State Environmental Protection Administration). 1999. The State Bulletin of China's Environment. Chinese Environmental Newspaper, 1999.6.17

Song, W. 1999. Development Strategy of Natural Gas for the 21st Century In China. Natural Gas Industry Journal, 19(4), 23-27.

State Bureau of Statistics. 1998. China Statistical Yearbook 1997. China Statistical Press. Beijing.

Wang, Q. 1998. Natural Gas Resource In China's Chemistry Industry and The Prospective. Natural Gas Industry Journal, 1998(7),15-23.

Wang, S. and H. Yu. 1998. Why is Green Energy Lagging Behind While the Environment is Getting Worse?. Beijing Youth Daily. October 5.

World Bank. 1997. Clear Water Blue Skies: China's Environment in the New Century. Washington D.C.

Xiao, J. 1997. International Natural Gas Consumption Situation and Development Perspective. Petroleum and Natural Gas Chemical Industry Journal. 26(2), 94-99.

Yang, J. 1998. Engineering Economic Analysis to Shan-Jing Natural Gas Pipeline. Natural Gas Industry Journal, 18(1), 77-81.

Zhang, S. et al. 1999. Marginal Cost Pricing for Coal Fired Electricity in Coastal Cities of China: The Case of the Mawan Electricity Plant in Shenzhen, Guangdong Province. EEPSEA Research Report.

LIST OF ACRONYMS

CNG	Compressed Natural Gas
CNGC	Chongqing Natural Gas Company
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corporation
CNSPC	China National Star Petroleum Corporation
CODC	Chuandong Oil Development Corporation
GSF	Gas Source Fee
HC	Human Capital
IIF	Initial Installation Fee
IRR	Internal Rate of Return
LDCs	local distribution companies
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MOFTEC	Ministry of Foreign Trade and Economic Cooperation
NBP	Net-back-price
NG	Natural Gas
NPV	Net Present Value
RMB	Chinese Currency "RenMinBi", 1US$=8.2RMB
SDPC	State Development Planning Commission
SETC	State Economic and Trade Commission
Sinopec Corp.	China Petroleum and Chemical Corporation
SPA	Sichuan Petroleum Administration
WTP	Willingness to Pay