Owning up to Responsibility for Manufacturing Contributions to the Pearl River Delta's Poor Air Quality

Bill BARRON, Simon NG Ka Wing and Ben LIN Chubin

March 2006

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OF SCIENCE AND TECHNOLOGY

In co-operation with:

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List of Acronyms

CLP	China Light and Power
cSt	centistokes
FGD	flue gas desulfurization
GW	gigawatt
GWh	gigawatt hour
HEC	Hongkong Electric Company
kWh	kilowatt hour
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MW	megawatt
MWh	megawatt hour
PJ	petajoule
PRD	Pearl River Delta
RMB	Renminbi

Energy Conversion Table

Energy	Conversion Factor				
Coal	20,908	kjoule/kg	2.0908	$\times 10^{-5}$	Pjoule/ton
Crude Oil	41,816	kjoule/kg	4.1816	$\times 10^{-5}$	Pjoule/ton
Fuel Oil	41,816	kjoule/kg	4.1816	$\times 10^{-5}$	Pjoule/ton
Diesel Oil	42,652	kjoule/kg	4.2652	$\times 10^{-5}$	Pjoule/ton
Gasoline	43,070	kjoule/kg	4.307	$\times 10^{-5}$	Pjoule/ton
Kerosene	43,070	kjoule/kg	4.307	$\times 10^{-5}$	Pjoule/ton
LPG	46,055	kjoule/kg	4.6055	$\times 10^{-5}$	Pjoule/ton
LNG	50,000	kjoule/kg	5	$\times 10^{-5}$	Pjoule/ton
Electricity	3,596	kjoule/kg	0.3596	$\times 10^{-5}$	Pjoule/ton

Source: *China Energy Statistical Yearbook 2004.*

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Hong Kong
March 2006

Opening Statement

Manufacturing directly and indirectly (via use of coal-fired public power generation) accounts for about three quarters of coal use in Guangdong, one third of all heavy fuel oil, and the sector's consumption of diesel fuel is roughly on a par with transport.

> Clearly, a substantial reduction in Hong Kong's air pollution 'imports' from Guangdong <u>must</u> involve the manufacturing sector through moves to cleaner fuels, more stringent emission controls, and energy conservation.

Hong Kong is the largest source of outside investment in Guangdong's manufacturing with more than 53,000 plants there in 2003. *So far, however, we have to conclude that the Hong Kong owners and managers of a large share of Guangdong's manufacturing have not faced up to their responsibility for much of the air pollution Hong Kong imports from across the border.*

For its part the Hong Kong Government has taken a laissez faire approach, despite the threat to the health of everyone in Hong Kong (seven months, on average, off the life expectancy of persons 45 and over and potentially much more off the lives of the young and the susceptible). If the trends are not reversed, chronic air pollution ultimately threatens Hong Kong's future as a world city.

Yet, because so much of the investment in Guangdong's manufacturing is from Hong Kong, there is potentially more leverage to clean up as opposed to the looming problems arising from the explosive growth in the motor transport sector. Indeed, if we do not deal with manufacturing emissions, the combination of manufacturing and future transport emissions could be nothing short of catastrophic.

Summary

The heavily polluted skies threaten to undermine the desirability of Hong Kong as a place to live and raise children. The pollution comes from both local sources and 'imports'.

Our own emissions make it hazardous for anyone to spend much time at street level where traffic is heavy. And under certain weather conditions, emissions from our coal-fired power plants are not effectively dispersed. For local sources the government knows what it would take to make major reductions (e.g., curtailing road transport and promoting rail, less coal and more natural gas for power generation, and more stringent emission controls at all of our coal-fired power plants). *That local pollutant emissions remain high reflects a lack of political will, rather than uncertainty over what actions to take.*

The problem of air pollution 'imports' becomes severe when prevailing winds are from the northeast or when there is little wind. Sources of air pollution in Guangdong include inefficient coal-fired power plants lacking effective emissions controls, growing vehicle fleets, heavy industry and the manufacturing sector. *For these pollution 'imports' there seems to be widespread presumption here that there is nothing Hong Kong can do about it. We believe this view is wrong.*

This study focuses on manufacturing in Guangdong because Hong Kong accounts for the largest share of outside investment in this sector with more than 53,000 factories in the province. We wanted to develop a series of case studies to shed light on the energy picture faced by Hong Kong-owned manufacturing plants operating in Guangdong. Concurrently, a companion study, by Christine Loh of Civic Exchange looked at the fuel supply situation on the Mainland. Together, we hoped the two investigations would help promote more active discussion of ways in which the region's severe air pollution problems might be addressed more forcefully.

In focusing on Hong Kong-owned and managed manufactures we hoped they would be willing to explore ways they might contribute to reducing pollutant emissions from their Guangdong-based plants, since Hong Kong itself is so severely affected. For those firms who agreed to be interviewed, this does seem to be the case. Unfortunately, the wider picture is not so encouraging.

Even with the support of several business associations, and promising confidentiality, firms were reluctant to be interviewed. In one case, *after initial enthusiastic expressions of interest by senior staff of one of the largest of Hong Kong business associations (to canvas members with factories in Guangdong to see who might be willing to be interviewed about their energy use), these persons suddenly became unavailable to us and further talks with the organization did not result in progress.*

> While the various voluntary initiatives being undertaken by Hong Kong's business associations with members having factories across the border are laudable, we question the extent to which the Hong Kong manufacturing sector overall recognizes that it must take *ownership* of a major share of our air pollution imports.
>
> For its part the Hong Kong Government has failed to promote emission deduction on the part of the Hong Kong-owned manufacturing sector in Guangdong, or even to speak out about it.

Background

In 2003 Guangdong had over 24,500 manufacturing establishments with annual revenues over RMB¥5 million. For *all* manufacturing establishments in Guangdong the official figure stood at almost at 413,000. Hong Kong is the largest source of outside investment in Guangdong's manufacturing and accounts for over 53,000 factories large and small. This includes over 18,000 in Dongguan and 16,000 in Shenzhen, cities where, due to climatic conditions, emissions have particularly strong impact on Hong Kong's air quality.

In recent years, the Guangdong manufacturing sector has been plagued with shortages in public power supply and most plants have resorted to buying their own generators. Despite the on-going shortages, Guangdong's public power generation capacity has been rising steadily. In 1998 it had a capacity of just over 29 GW. By 2003 this had risen to almost 40 GW, nearly a 35% expansion in just 5 years. Yet the growth of manufacturing demand has been even faster, resulting in shortages. In 2003 thermal power plants accounted for 76% of electricity generation, followed by nuclear at 15% and hydro at 8%. Within thermal generation coal accounted for 73%, and oil-fired plants for 27%.

In 2003 'manufacturing' accounted for 45% of all public power consumption in Guangdong. Consumption of public power supply to the textiles sub-sector rose far less sharply than the value of its output. Meanwhile 'Textiles' consumption of coal rose substantially. The trend in textiles appears to be towards self-power generation using small coal-fired steam plants as a cost saving measure.

In 2003, the major direct users of coal in Guangdong were 'Nonmetal Mineral Products', 'Paper Making and Paper Products', 'Food Processing', and 'Textile'. *Manufacture's consumption of coal was two thirds that of the power sector's.* Its use of coal is also rising, increasing 20% *between 2000 and 2004*. For details of sub-sectoral direct coal consumption see Table 3 in the main report.

> In 2003 manufacturing in Guangdong consumed 205 PJ of fuel oil and 152 PJ of diesel fuel. This was 78% as much fuel oil as used for public power generation, and 90% as much diesel fuel as consumed by transport.

In 2003 the split of industrial energy end-uses in Guangdong was coal (52%), fuel oil (17%), diesel fuel (13%), other petroleum (12%), LPG (3%), and refinery gas (3%). *Considering its consumption of public electricity (most of it coal-based), as well as its direct use of coal manufacturing is responsible for three fourths of all coal used in Guangdong.* Unless coal is low sulphur and ash to begin with and unless there are state-of-the-art stack gas emission controls, coal is highly polluting.

In short no meaningful solution to air pollutant emissions in Guangdong can be accomplished without addressing the manufacturing sector and that means Hong Kong-owned and managed business must play a major part.

The Interviews

We were able to secure twelve interviews with manufacturers located in Guangdong. Of these, eleven must rely on their own power generation for part or all of their power needs. Of those generating their own power, three need do so only for a moderate portion of their needs, but for the remaining eight plants reliance on self-generation ranged from a low of 15% of total electricity usage up to 100%. We tested nine samples of 0# diesel fuel from the interviewees, which was the main source of fuel for self-generation, and found that while sulphur content was generally low at 0.33% on average, it varied greatly from a high of 0.96%, well above the legal limit for 0# diesel of 0.5%, to a low of 0.08%. We also obtained one sample of fuel oil and its sulphur content was 2.56%. This fuel oil sample also had nearly 1% water content.

The major factor in determining reliability of grid electric power is plant location though other factors come into play as well. The local grids are not well interconnected and supply tends to be localized. Shortfalls also go beyond generation to the transmission system. Some plants with high power needs were unable to obtain permits for adequately sized transformers. It also seems that in some cases, local officials used the rationing of available power supplies as a negotiating tool with manufactures.

One encouraging note is that except for one interviewee, each self-generator reported that it costs more to self-generate than to get power from the grid and none of these had plans to continue self-generation once grid supply becomes fully reliable.

Except for one manufacturer which uses a 14 MW coal-fired steam power generator, our interviewees who self-generate do so with diesel engines and each uses 0# diesel fuel. Our interviewees are, however, certainly not typical. Many plants use much lower grades of diesel fuel and where their equipment can tolerate it, sometimes fuel oil to generate their own power.

For manufactures with large process heat requirements (in particular steam heat), self-generation using coal or high sulphur fuel oil is likely to be less expensive than drawing on grid power. *Thus, while expansion of grid generating capacity will cut back on much of the manufacturing self-generation, especially by smaller plants, manufacture's use of coal and high sulphur fuel oil would be largely unaffected.*

A Second Best Solution

Normally, the most cost-effective first step in reducing air pollution is to upgrade the fuel being used, either by fuel switching (e.g., from solid to liquid, or liquid to gas) or when staying within a certain type of fuel to move towards ones with lower sulphur, and other contaminants. However, the difficulties noted by our interviewees with respect to the severely restricted options for choosing fuel suppliers and the tight supply of higher quality fuels, such steps appear to be of limited practicality until the fuel supply situation improves. As Loh notes in her companion study, the increased supply of cleaner fuels will require dismantling the current system of fuel price controls.

> Until cleaner fuels become much more readily available in Guangdong, Hong Kong's manufacturing in the province should focus on *energy efficiency improvements* and conservation.
>
> The Hong Kong Government should look for ways to encourage – and indeed facilitate – such moves, for example through investment assistance and codes of practice.

It is important to keep in mind that it is highly unlikely that our interviewees are representative of Hong Kong-owned firms and certainly not of those Guangdong manufacturing firms whose capital and management comes from within

Mainland China or from other places (e.g., Taiwan, Korea). This is likely to be particularly true with respect to their reliance on 0# diesel fuel for power generation. The typical diesel fuel user is using a much lower grade of diesel and where feasible high sulphur fuel oil or coal.

The Broader Energy Supply Picture

The rapid growth of China's oil consumption has strained the nation's refining capacity. The gap in supply relative to demand for particular types of fuel tends to be filled by local private refineries who provide fuel of lower quality. As Loh mentions, suppliers and traders believe that as much as 40% of the oil products used in Guangdong today come from such non-official sources.

While Sinopec and PetroChina are expanding and up-grading their refining processes to produce cleaner fuels, World Trade Organization (WTO) stipulations mean that by the end of 2006 foreign oil companies will be allowed to distribute wholesale imported petroleum crude and products. Oil product *imports* via the state-owned oil companies are already a major part of the Guangdong energy picture. In 2003 provincial petroleum refiners produced 103 PJ of fuel oil, while a net of 431 PJ were imported.

> Following coal, high sulphur fuel oil is the most polluting of industrial fuels. The high level of imports offers the potential to reduce pollution from this fuel by sourcing higher grades. However, this will only happen if (i) consumers are willing to pay the higher prices; (ii) importers are willing to import it in quantity; or (iii) governments mandate its use in particular circumstances.
>
> A key feature of the energy situation in China is the state controls on prices. The problem is that while the importers must pay international prices authorities have not allowed the full effect of the higher fuel costs to be reflected in the prices paid by consumers for oil products.

Conclusion

The problem of addressing manufacturing air pollution in Guangdong is a difficult one. Things should improve to a moderate degree by 2008 when the public power system is expected to have adequate generation capacity and there will be cut backs on self generation *unless the added public power supply is offset by expansion of the manufacturing base.* With the opening up of the China fuel market, there will be greater potential to bring in cleaner fuels. However, voluntary measures alone are unlikely to create a substantial demand for higher priced cleaner fuels. Another positive change in southern Guangdong will be the 4 new clean natural gas-fired power plants with a generation capacity of 4.2 GW.

In the longer term, if LNG supplies can be attained at an acceptable price, it would be possible to build a gas distribution network for industrial estates in southeast Guangdong. *Such a move, if coupled with government requirements to use the gas in place of liquid fuels in manufacturing, could make manufacturing output in the eastern PRD much less of an environmental threat than it is today.*

Yet, despite these rays of hope, in the near term prospects are not bright.

- First, coal *will* remain the major source of power generation and a major industrial fuel in Guangdong;
- Second, those sub-sectors relying on coal or heavy fuel oil are likely to continue to self-generate their own power because it is cheaper;
- Third, the constraints on public power supply are not only ones in generation, but in some case of transmission line capacity;
- Fourth, to initiate a widespread clean up, higher quality fuels must be readily available. This is unlikely until price controls are eased;
- Fifth, higher energy prices are providing an incentive for manufactures to switch to cheaper dirtier fuels;
- Sixth, there must be enforced stringent environmental mandates on manufacturing. Given our experience, we see little hope in voluntary measures beyond token feel good initiatives; and

- Finally, we must reduce manufacturing emissions before we face the effects of high manufacturing emissions combined with emissions from an exponentially expanded Guangdong motor vehicle fleet.

Recommendations

1. The Hong Kong Government should be explicit in stating Hong Kong has a direct interest in Guangdong's fuel sector and looks forward to:

- Lifting price controls on petroleum products.
- Discouraging (and as appropriate *banning*) high sulphur fuel oil for any industrial purpose once supplies become more flexible.
- Eliminating use of diesel fuel above 0.5% sulphur for *any* purpose and move gradually toward much lower sulphur content (e.g., < 0.05%).
- Considering the major role of coal, ban the use of coal above 1.5% sulphur and as feasible require use of FGD and other stack gas emission controls for all coal-fired power plants above 15MW.

2. The Hong Kong Government should work with Hong Kong-owned manufacturing establishments in the PRD to:

- Invest in energy efficient equipment and processes.

3. Hong Kong's business associations with members who own and manage factories in Guangdong should:

- Work to raise awareness among their members about responsibility toward reducing the Territory's 'imports' of air pollution from across the border.
- Work to establish energy audits for the larger firms.

4. Hong Kong manufacturing establishments in Guangdong should:

- Take the lead in energy conservation.
- As cleaner fuels become available, pledge to use the cleanest fuel.

Full Report

On the way to the interview the air was noticeably smoky. We felt it in our eyes and throats. Back in Hong Kong, this day in January the air lacked the grittiness it had in eastern Guangdong, but even so, Hong Kong's air was damaging the health of all who breathed it.

The Hong Kong-owned and managed factory we had come to interview about its energy use generates all of its power from diesel generators (ten million kilowatt hours annually). The problem goes beyond generation capacity in the local public grid. The local transmission system is incapable of carrying the loads this factory and its two larger neighbours need. One neighbouring factory generates its power from high sulphur fuel oil, the other from coal. The tall smoke stacks of each of the neighbours bellow out a steady stream of black smoke.

Introduction

We begin with this anecdote firstly to provide an impression of the situation *on the ground* with respect to energy use and air pollution and secondly, to note that limited electric grid generation capacity, while important, is not the only reason for highly polluting industrial-scale self-power generation. Transmission capacity can also be a constraint. Thirdly, it reminds us that given the difficulty in getting facts on the ground, one may have little choice but to begin with particular pieces of information as an initial foundation for further work.

And begin we must, for the air we breathe in Hong Kong is poisoning us.[1] While Guangdong's public power plants, its growing vehicular fleets, and state-owned heavy industry all contribute to Hong Kong's air pollution *imports*, so too does manufacturing.

> Fortunately here, we *potentially* have considerable leverage because Hong Kong-based firms are the largest source of outside investment in Guangdong's manufacturing with more than 53,000 factory facilities, employing about 10 million workers.[2]
>
> In 2003 manufacturing accounted directly and indirectly (via use of coal-based public power) for three out of every four tons of coal consumed in Guangdong, as well as one of every three litres of fuel oil (including that used in oil refining and public power generation), and used almost as much (90%) diesel fuel as the transport sector.

> *If pollution imports from Guangdong are <u>ever</u> to be seriously curtailed, the manufacturing sector, and Hong Kong's role in it, must take a truly leading role in that effort.*

Yet, the various voluntary campaign efforts to clean up not withstanding, there does not appear to be a widespread acknowledgement of the responsibility Hong Kong firms with plants in the PRD have in creating the Territory's chronic air pollution. And while the Hong Kong Government has done much to limit

[1] Major pollutants such as nitrogen dioxide, sulphur dioxide and respirable suspended particulates are strongly associated with cardio-respiratory diseases in Hong Kong. To read further on studies on short-term health impact of ambient air pollution, visit http://www.epd.gov.hk/epd/english/environmentinhk/air/studyrpts/effect_ambient_ap.html

[2] Federation of Hong Kong Industries, *Made in PRD*, Hong Kong, 2003.

pollution from factories still within Hong Kong, it has taken a laissez faire approach to the behaviour of Hong Kong-owned and managed factories just across the border, as if such an extension of oversight was simply out of the question. To be sure, exerting influence on Hong Kong firms' activities outside Hong Kong is not nearly so straightforward as controlling their activities at home. Nonetheless, there are precedents elsewhere in the world. *And when all is said and done, considering that the health of all of us, and arguably Hong Kong's future as a world city is at stake, is such a hands-off approach really a viable option?*

Since the late 1990s Hong Kong and the rest of the Pearl River Delta has experienced chronic air pollution. On the Hong Kong side the major polluting sectors are transport and power generation. For much of the transport sector and power generation, local standards on fuel quality, and combustion equipment are relatively advanced. Nonetheless, emissions from local road transport, make it unhealthy for any of us to spend time near congested roads in Hong Kong. The very high risk comes from the fact that, unlike pollution emitted from the tall smoke stacks of power plants, emissions from vehicles are literally in the faces of pedestrians and passengers in other vehicles and so are inhaled in much higher concentrations. One fundamental approach for transport is to build fewer roads and more rail lines, so that the share of rail increase from one third of public transport journeys it is today to 50% or more. For the power sector, there is also much more than can be done to reduce emissions from coal-fired power plants, especially use of flue gas desulfurization (FGD) at China Light and Power's (CLP's) Castle Peak plant. Most basically we need to increase the role of natural gas. Proposals and plans for the use of LNG are in the works at both CLP and Hongkong Electric (HEC).

> In short, we *know how* to reduce pollutant emissions from within Hong Kong. The fact that we have not done more to clean up our own act is a failure of *political will* to face up to the higher costs of implementing fundamental changes (e.g., more reliance on rail; less coal in power generation).

> Unfortunately, we have *not come even so far as to seriously evaluate what the options* are for making a major dent in our pollution imports.

Across the border (but within our shared air shed) pollutant sources are more varied, with numerous old power plants many of which burn low grade coal and are highly inefficient, tens of thousands of small manufacturing power generators, hundreds of large manufacturing power and process heat plants, and rapidly expanding road transport being the major contributors. In fact over the long term, it will likely be motor transport in Guangdong which continues to experience exponential growth that will prove to be the most challenging sector to deal with in environmental terms. Meanwhile, however, manufacturing emissions are more important and in certain respects could be more readily addressed.

In this study we focused on the Hong Kong-owned and managed manufacturing facilities in Guangdong, attempting to learn what we could about self-power generation, industrial process heat needs, and the fuels used to meet these demands. In this, we were primarily concerned with (i) their energy requirements, and (ii) the energy supplies available to meet those needs. Prospective interviewees were promised confidentiality with regard to their individual responses to our questions. The interview instrument is shown in Appendix I.

Working in collaboration with individual companies, an oil products supplier, and several Hong Kong business associations with members who own and operate factories in Guangdong, we attempted to arrange as many face-to-face interviews as possible. The aim was not to produce a statistically representative survey (we did not have the resources for that). Rather, we hoped to develop a series of case studies which would shed light on the energy situation faced by such firms and options for emissions reductions, especially through the use of cleaner fuels. We hoped that even a limited number of case studies would provide us with a clearer understanding of the energy needs and of the fuel availability/pricing situation faced by industrial establishments in the PRD. A concurrent companion study, conducted by Christine Loh of Civic Exchange,[3] examined from a more macro perspective the fuel supply situation on the Mainland in general and in Guangdong in particular. In combination, we hoped the two investigations would help promote more active discussion of ways in which the region's severe air pollution problems might be addressed more forcefully.

In focusing on Hong Kong-owned and managed industrial establishments in Guangdong, we hoped that these, on average, would be both reasonably well informed about the seriousness of the air pollution and more willing to explore ways in which they might make a contribution to reducing it, since Hong Kong itself is so severely affected. For those firms who agreed to be interviewed, this does, in fact, seem to be the case.

Unfortunately, the wider picture is not so encouraging. Firstly, even working with the support of business associations, and promising confidentiality, firms seemed reluctant to be interviewed. Secondly, the reluctance also sometimes extended to Hong Kong's business associations themselves. Only some of the business associations we approached agreed to cooperate with us.[4] In one case, after initial enthusiastic expressions of interest by senior staff of one of the largest Hong Kong business associations – to canvas members with factories in Guangdong to see who might be willing to be interviewed about their energy use – those staff persons abruptly became unavailable to talk with us and subsequent discussions with their designated replacements proved fruitless.

In light of this and other experiences, we feel we must question the extent to which the Hong Kong's manufacturing sector, the largest source of outside investment in Guangdong with over 53,000 factories just across the border, recognizes that it must take *ownership* of a major portion of the air pollution problem coming our way.

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[3] See Christine Loh, *Energy Supply and Fuels Supply in Guangdong: Impact on Air Quality in Hong Kong and Guangdong,* Civic Exchange, Hong Kong, March 2006. http://www.civic-exchange.org/publications/2006/energy.pdf

[4] The two organizations that were most helpful in identifying prospective interviewees for us were the *Swiss Business Council in Hong Kong* and *the Business and Professionals Federation of Hong Kong.*

While the various voluntary initiatives by different business groups on cleaner production are to be applauded, we nonetheless feel that much more widely supported – and more focused – initiatives (on clean fuels and energy efficiency) are urgently needed.

Background

In 1989 Hong Kong had almost 50,000 manufacturing establishments employing nearly 800,000 workers. By 1994 those figures had dropped to 34,000 and 439,000 respectively. By 2004, less than 16,000 manufacturing establishments remained employing 165,000 workers. Thus, over a decade and half the number of Hong Kong's manufacturing establishments fell to less than a third of its former level while manufacturing employment was only one fifth the level fifteen years earlier.[5]

The decline in Hong Kong's manufacturing is mirrored by the *increase* in manufacturing in Guangdong. In 1989 Guangdong had about 426,000 manufacturing establishments, and the number rose to almost 525,000 in 1994. The official figure stood at 413,000 in 2003.[6]

Guangdong classifies 'Electronic Information', 'Petroleum and Chemistry' (e.g., raw chemical products and rubber products) among its upcoming industries. Electronic information, including computers and other electronic equipment, accounted for about 28% of total output in the province in 2004. Meanwhile, some important sectors for early Hong Kong investment such as 'Textiles and Garments', and 'Food and Beverages' are classified as traditional industries. In 2004 'Textiles and Garments' accounted for about 7% of the total of gross value of output in the province, while 'Food and Beverages' accounted for about 6%.

[5] Hong Kong SAR Government, *Hong Kong Yearbook*, various years, Hong Kong.
[6] Bureau of Statistics of Guangdong Province, *Guangdong Statistical Yearbook*, various years, China Statistics Press, Beijing; Guangdong Yearbook Editing Committee, *Guangdong Yearbook*, various years, Guangdong Yearbook Press, Guangzhou.

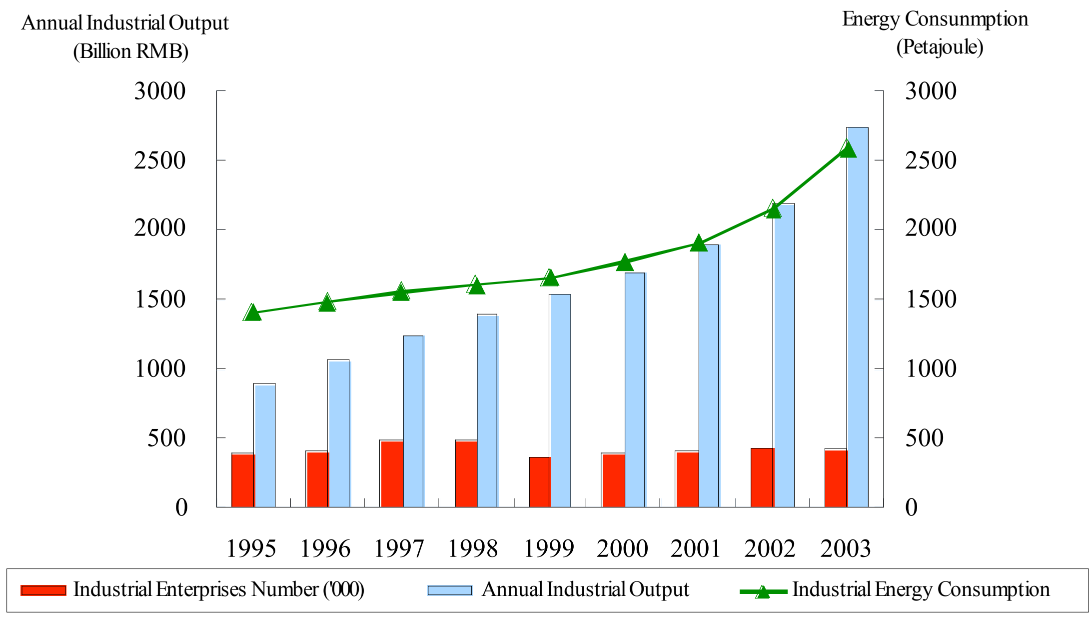
In 2004 out of Guangdong's total of about 26,000 establishments with annual revenue over RMB¥5 million[7], 18% were in Guangzhou, 8% in Dongguan and 9% in Shenzhen.[8] And with the prevailing wind patterns in the region, it is emissions from these cities which have the greatest impact on Hong Kong.[9] For this reason we report city specific manufacturing information below for Guangzhou and Shenzhen, along with more limited information we have for Dongguan.

In terms of the gross value of industrial output Guangzhou accounts for 19% of the provincial total, Dongguan 10% and Shenzhen 24%.[10] Thus, manufacturing establishments in these cities are above the provincial average in terms of their economic importance, especially in the case of Shenzhen.

The overall picture of manufacturing growth in Guangdong over the past decade and a half or so is one of rapid growth, a changing direction of growth over time and considerable differences among cities in the size and mix of industries. As noted below, it is also a time in which the infrastructure for energy supplies, often failed to keep pace with skyrocketing demand. (Figure 1)

[7] It has become the definition for "industrial enterprise above designated size" after 1997 in statistical yearbooks.
[8] Bureau of Statistics of Guangdong Province, *Guangdong Statistical Yearbook*, 2005, China Statistics Press, Beijing.
[9] See Lo, Lau and et.al., "Investigation of enhanced cross-city transport and trapping of air pollutants by coastal and urban land-sea breeze circulations", forthcoming, *Journal of Geophysical Research – Atmospheres*.
[10] Bureau of Statistics of Guangdong Province, 2005, op.cit.

Figure 1 Industrial Enterprises Number, Annual Output and Energy Consumption in Guangdong (1995-2003)



Sources: *Guangdong Statistical Yearbook*, various years.

The Interviews

After discussions with a number of business associations, one fuel supplier, and some individual companies, we were able to secure only twelve interviews with manufacturers located in Guangdong. Of these, eleven must rely on their own power generation for at least part of their power needs[11] – three had to do so only for a relatively moderate portion of total power needs, whereas for the remaining eight plants self-generation ranged from a low of about 15% of total electricity usage to 100%. The primary determining factor in the reliability of grid electric power is plant location. However, in some cases limited power appears to be directed to certain preferred customers, especially the long established ones or those seen as being more advanced.

In other words, the individual local grids are not well interconnected and so supply is highly localized. Further, as demand has outstripped supply in

[11] The only one that could fully rely on the grid was located in central Guangzhou.

particular places, power shortages are not necessarily shared equally among newer and older or major and minor consuming manufactures. Indeed, there seem to be cases in which officials have used the allocation of power supply as a bargaining tool in negotiations with plant managers. Also, as noted below, a plant's level of peak demand can also present problems in obtaining adequate grid power or grid power at all. Those with relatively high peak demands (in the range of MWs) may simply be unable to obtain a permit for a suitably sized transformer. With the exception of one plant we interviewed, each of the self-generators reported that it costs them more to self-generate than to get power from the grid.[12]

> Nonetheless, it is likely that firms will keep their generators as back up not only on the possibility of future generation capacity shortages but also as a way of giving them greater control over this crucial aspect of production.[13]

This is encouraging news, since grid capacity shortages are expected to be greatly reduced within a few years. Nonetheless, the legacy of the history of power shortages is pervasive. One plant which wants to expand its operations but must move to another location in Guangdong in order to do so, listed *reliability of local grid power supply*, along with land costs and water supply as the major criteria for choosing a site. Also, most plants are likely to keep their generator sets as insurance against possible future grid power supply shortages.

Except for one manufacturer which uses a 14 MW coal-fired power generator, our interviewees who self-generated do so with diesel engines. While the total generation capacity at each plant varied considerably, from about 250 KW (or 0.25 MW) to a very substantial 30 MW, each relied on one or more individual generators that ranged in capacity from 0.25 MW up to about 1.4 MW each.

[12] One plant reported that a kWh of self-generation was 40% more costly than a kWh off the grid. Another interviewee reported that when considering both fuel and generator maintenance costs self-generation was 60% per kWh more expensive than grid power.

[13] Most interviewees who experienced significant grid power shortages thought it would be 2008 at the earliest before their local public grid power becomes fully reliable.

The amount of power generated by the interviewees, as would expect, also varied considerably. The smallest annual amount of self-generated power among those of our interviewees was about 300,000 kWh, or 0.3 GWh per year. More typically, the levels were above 10 million kWh and often in the *tens of millions* kWh (i.e., in the range of *tens of* GWh). About half of the plants interviewed had peak power demands exceeding 1 MW and obtaining permits for the appropriately sized transformers is sometimes a problem. One of our interviewees is in an area where the transmission network is incapable of supplying even off peak demands in the range of several MWs. This plant along with its larger neighbouring factories self-generate *all* of their own power.[14]

For industries with large process heat requirements (in particular steam heat), self-generation using coal tends to be less expensive than drawing on grid power. Such plants also use considerable amounts of fuel oil. Two of the non-textile plants interviewed, both large operations with substantial process heat requirements, used fuel oil (2% to 2.6% sulphur) to meet those needs. There were indications that cost and availability considerations were broadly encouraging the use of fuel oil with higher sulphur content (e.g., up to 3.5%).

> While expansion of grid power generating capacity will cut back on much of the manufacturing self-generation, especially from smaller plants, manufacture's use of coal and high sulphur fuel oil would be largely unaffected. In addition, supply constraints and higher costs for lower sulphur fuel oil and coal appear to be encouraging the use of more polluting fuels for non-electric process heat needs.

We asked the companies about the significance of fuel costs as a proportion of all variable costs. However, the answers provided were clearly based on inconsistent assumptions about what they included in the calculations. About all we can say is that, with the exception of firms with very high process heat

[14] At present the neighboring factories (one using coal and one fuel oil), like our interviewee using diesel fuel are exempted for requirements to use FGD but such controls are expected in the near future.

demands (e.g., textiles), fuel costs account for a moderate but potentially significant share of operating costs – very broadly in the range of about 5% to 20%.

Hence, these companies have relatively strong incentives to use cheaper lower quality fuel, so long as it does not impair their equipment or its performance. Yet, for many and perhaps most firms, energy is a small enough part of their operating budget that a moderate price penalty for cleaner fuel (for example up to a 15% price increase) could be absorbed, if need be.[15]

While in each case the diesel fuel purchased by our interviewees is listed as 0# diesel (the highest grade), many expressed concern about its quality, including such things as water content and other contaminants. In general, the interviewees also indicated that they had little or no choice among fuel suppliers and quite limited options with respect to higher quality fuels.

We were able to collect 9 samples of diesel and one of fuel oil from the interviewees and had these analyzed for sulphur content, moisture and viscosity. The fuel oil sample had a relatively high sulphur content of 2.6%, a moisture content of 0.9% and viscosity of 181.7 cSt. High moisture content and high viscosity hinder combustion efficiency and so tend to add to pollution. (See Appendix II for full analysis results)

Interestingly, among the nine 0# diesel samples the sulphur levels were quite varied. The two highest levels were 1.4% and 1.0%, while the lowest were only 0.08% and 0.16%. The mean was 0.33%, which is actually below the Hong Kong industrial standards of 0.5%.[16]

[15] For example if fuel amounted to 5% of variable cost and its price rose by 15%, variable costs as a whole would go up by 0.75%; if fuel accounted for 20% of all operating costs, a 15% fuel price rise would increase operating costs by 3%.
[16] For comparison we also tested two industrial diesel fuel samples from Hong Kong and these had sulphur contents of 0.495% and 0.411% respectively.

With the exception of the fuel oil sample the moisture contents were below 0.05%, which is acceptable. Viscosity for the diesel fuel samples while quite varied (from 3.2 to 7.2 cSt) were nonetheless within an acceptable range.

Our analysis of the fuel samples serves as reminder of the high degree of variability of fuel in Guangdong even within a specific grade. And while our interviewees use the highest grade, many (and perhaps most) other manufactures do not. And then there is the problem of the adulterated cheaper diesel coming from the small private refineries. [17]

A Second Best Solution

Normally, the most cost-effective first step in reducing air pollution is to upgrade the fuel being used, either by fuel switching (e.g., from solid to liquid, or liquid to gas) or when staying within a certain type of fuel to move towards ones with lower sulphur, and less of other contaminants. However, the difficulties noted by our interviewees with respect to the quite limited options for fuel suppliers and their ability to locally source fuel of higher quality, such steps appear to be of limited practicality until the fuel supply situation in Guangdong and indeed in the whole of China improves.[18] In light of this, energy efficiency in combustion and end-use, along with energy conservation by way of better process design become the major options. Such measures also have the advantage of potentially being net cost savers to the manufactures through lower energy bills.

> Until cleaner industrial fuels become much more readily available in Guangdong, Hong Kong's manufactures in the province should focus on energy efficiency improvements and conservation.

[17] For a discussion on fuel adulteration, see Loh, op.cit., pp.30-31.
[18] Loh, op.cit.

> The Hong Kong Government should look for ways to encourage such moves, for example, through investment assistance for energy efficient equipment, and codes of practice on the part of Hong Kong-owned and managed manufacturing plants in Guangdong.

A Widespread Problem with Local Variations

Broadly, the picture that emerged from the interviews is one of widespread grid power shortages (typically in generation capacity but sometimes in transmission capacity as well), which in some places limited the availability of high capacity transformers for firms with high levels of peak demand, i.e., more than several MWs. Yet the severity of the situation varies greatly from one locale to another and sometimes from one plant to another in the same vicinity. For many firms in the province it would appear that grid power is simply unavailable due to inadequate transmission capacity, for some it is unavailable one or two days each week, while for others power disruptions are only occasional and of short duration, and for some plants, it is fully reliable. And in places and times of shortages allocation of available electricity supplies may become a matter of negotiation with local officials.

In wrapping up what we can say from the limited number of interviews we were able to arrange, it is important to keep in mind that it is highly unlikely that our interviewees are representative of Hong Kong-owned firms and certainly not of those Guangdong manufacturing firms whose capital and management comes from within Mainland China or from other places. This is likely to be particularly true with respect to their reliance on 0# diesel fuel for power generation. The <u>typical</u> diesel fuel user is more likely to be using a lower grade of diesel.

Energy Situation in Guangdong

Public Grid Electric Power

As shown in Table 1 Guangdong's public generation capacity has been rising steadily.[19] In 1998 it had a capacity of just over 29 GW. By 2002 this had risen to almost 36 GW (nearly a one quarter expansion in a mere 4 years, a truly staggering rate of increase). By 2003 the combined public generation capacity had reached 39.2 GW, a 9% increase from 2002.

In 2003 the mix of Guangdong's electric power generation capacity was: thermal 69%, hydro 21%, nuclear 10% and wind 0.002% (See Table 1). The mix within thermal power was coal 63%, fuel oil and diesel 37%. There was also a small amount of waste to power (0.0004% of thermal power generation).

For electricity output, thermal power generation accounted for 76%, hydro 8%, and nuclear 15%. Wind provided 0.0008%. With thermal power generation coal accounted for 73%, and oil-fired plants for 27%.

As shown in Table 2 in 1998 public power generators in Guangdong provided 45,425 GWh to manufacturing establishments. By 2003 that figure had doubled to 90,834 GWh. 'Industry' including 'Electric Power, Gas and Water Production and Supply' accounted for about 70% of all power sales. However, if this sub-sector is excluded, then 'Manufacturing' alone accounted for 45% of all public power consumption in Guangdong in 2004 (see Figure 2).

[19] Go to Appendix III for a full table.

Table 1 Guangdong Public Electricity Power Capacity (in MW) and output (in GWh), 1998 and 2003

	1998	2003
Generating Capacity (MW)	**29,070**	**39,202**
1. Hydro-power	5,512	8,107
2. Thermal-power	21,716	27,231
Coal-power		*17,058*
Oil-power		*10,163*
Waste-power		*11*
3. Nuclear-power	1,800	3,780
4. Wind-power		83
Electricity Generation (GWh)	**103,854**	**189,577**
1. Hydro-power	15,287	17,136
2. Thermal-power	75,550	143,351
Coal-power		*104,459*
Oil-power		*38,950*
Waste-power		*64*
3. Nuclear-power	12,938	28,930
4. Wind-power		159
Electricity Imported from other Provinces (GWh)		**24,300**
Electricity Exported to Other Provinces (GWh)		**10,747**

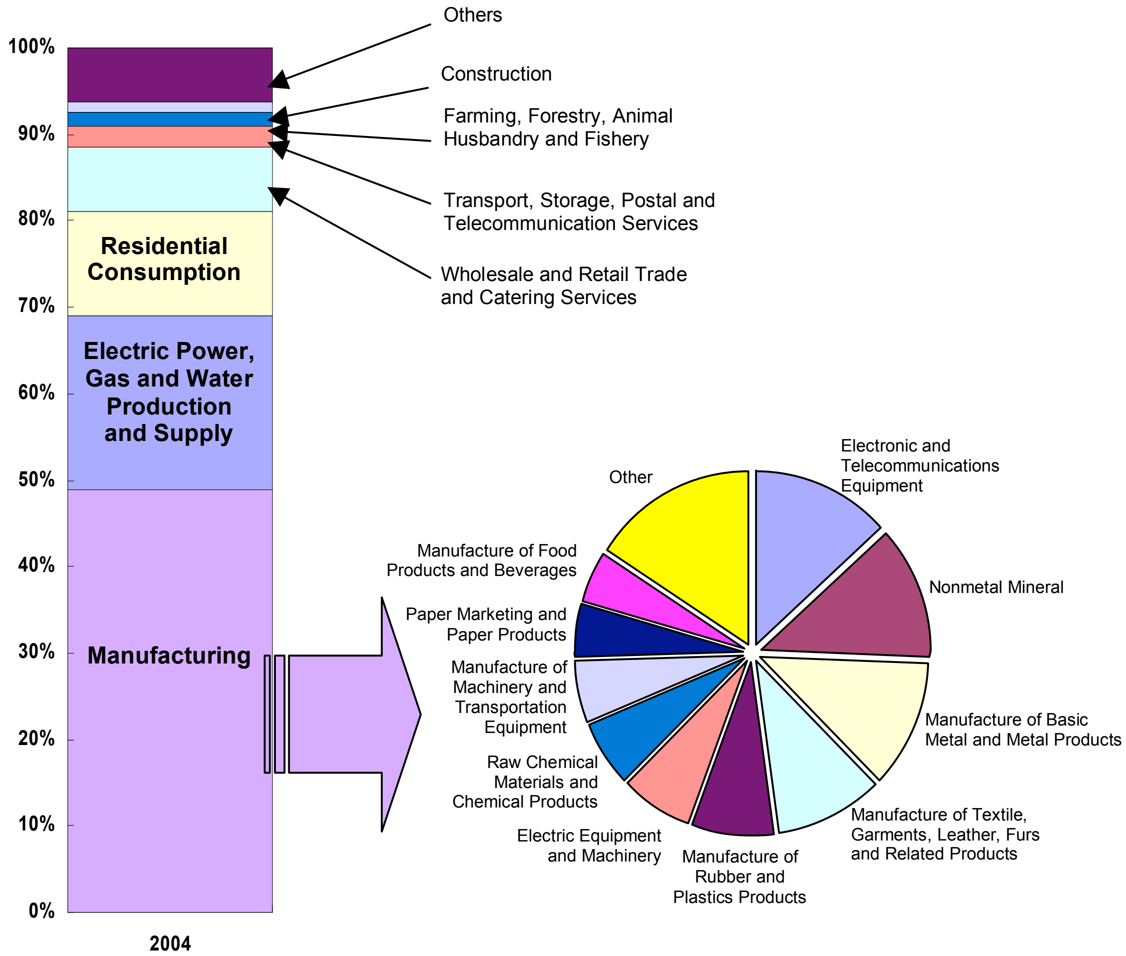
Source: *China Electric Power Yearbook 2004.*

Table 2 Guangdong Public Electricity Power Consumption for Selected Industrial Sub-sectors (in GWh), 1998 and 2003

	1998	2003
Net Electricity Consumption	**98,785**	**203,129**
Electricity Consumption in Industrial Sector	**62,969**	**136,884**
Manufacturing	**45,425**	**90,834**
Food Processing	*1,815*	*2,450*
Foods Production	*944*	*1,326*
Beverage Production	*414*	*782*
Tobacco Products	*78*	*105*
Textile Industry	*2,946*	*5,524*
Garments and Other Products	*1,196*	*2,988*
Leather, Furs, Down and Related Products	*655*	*2,202*
Timber Processing, Wood, Bamboo, Cane, Palm Fiber and Straw Products	*277*	*695*
Furniture Manufacture	*144*	*1,007*
Paper Making and Paper Products	*2,203*	*4,886*
Petroleum Processing, Coking and Nuclear Fuel Processing	*980*	*1,749*
Raw Chemical Materials and Chemical Products	*2,786*	*5,983*
Chemical Fiber	*972*	*565*
Rubber Products	*2,318*	*746*
Plastic Products	*2,980*	*6,524*
Nonmetal Mineral Products	*7,517*	*13,542*
Smelting and Pressing of ferrous Metals	*2,137*	*5,456*
Smelting and Pressing of Non-ferrous Metals	*698*	*1,971*
Metal Products	*3,148*	*4,106*
Electric Equipment and Machinery	*1,699*	*6,186*
Electronic and Telecommunications Equipment	*2,195*	*11,019*

Sources: *Guangdong Statistical Yearbook*, various years.

Figure 2 Breakdown of Guangdong Public Electricity Power Consumption by Industries and by Manufacturing Sub-sectors, 2004



Source: *Guangdong Statistical Yearbook* 2005.

Perhaps tellingly, public power to the 'Textile' sub-sector rose less sharply than in manufacturing as a whole and actually fell slightly from 2002 to 2003. Since the value of output in the 'Textile' sub-sector rose from RMB¥535 million in 2000 to RMB¥921 million in 2004,[20] the significantly less than proportional increase in grid electric power probably reflects the move toward full time self-power generation using coal on the part of larger textile plants with substantial steam heat needs. Evidence for such the increasing reliance on coal may be seen

[20] Bureau of Statistics of Guangdong Province, 2005, op.cit.

in the more than three fold increase in the sub-sector's coal consumption between 2000 and 2003.[21]

Both the 'Chemical Fibers' and 'Rubber Products' sub-sectors also saw dramatic declines in public grid electric power consumption. However, in both cases these were economically declining sub-sectors and their use of coal also declined.[22]

In contrast to the above cases, public grid power supplied to the 'Garments' sub-sector rose by 250% over the period to 5,524 GWh, while that to 'Leather and Related Products', along with that to 'Food Production', 'Food Processing', and 'Beverage Production', also rose substantially. Consumption of grid electric power for 'Electronic and Telecommunications Equipment' rose 500%, from 2,195 GWh in 1998 to 11,019 GWh in 2003, exceeding grid electric power consumption for all other industrial sub-sectors except 'Nonmetal Mineral Products'.[23]

Since 2003 and continuing through the coming several years the pace of grid expansion has been (and will continue to be) quite high. And starting in 2006, part of this expansion in public electric power supplies will be from clean natural gas, supplied by the LNG import terminal in Shenzhen.

Coal

Looking to Guangdong's primary energy supply in 2004, coal accounted for 58%, crude oil 30%, non-fossil fuel power 8%, and others 4%. About two thirds of Guangdong's fossil fuel electricity was generated by coal-fired power plants. In 2004 manufacture used 627 PJ of coal energy compared to the 939 PJ that went into public power generation.[24] (See Table 3)

[21] Bureau of Statistics of Guangdong Province, various years, op.cit. See also Table 3.
[22] Bureau of Statistics of Guangdong Province, various years, op.cit.
[23] China Electric Power Yearbook Editorial Committee, *China Electric Power Yearbook 2004*, China Electricity Power Press, Beijing, 2004.
[24] For a fuller description of energy flows in the province please refer to Appendix IV and Appendix V for Guangdong's 2003 and 2002 energy balance sheet respectively.

Table 3 Guangdong Coal Consumption for Selected Industrial Sub-sectors (in Peta-Joule) in Selected Years, 1998 -- 2004

	1998	2000	2003	2004
Net Coal Consumption	**1,045**	**1,220**	**1,636**	**1,804**
Coal Consumption in Industrial Sector	**994**	**1,187**	**1,611**	**1,775**
Manufacturing	**539**	**528**	**776**	**630**
Food Processing	*104*	*94*	*88*	*59*
Foods Production	*19*	*17*	*25*	*13*
Beverage Production	*8*	*10*	*10*	*6*
Tobacco Products	*1*	*1*	*1*	-
Textile Industry	*20*	*21*	*69*	*69*
Garments and Other Products	*1*	*1*	*8*	*6*
Leather, Furs, Down and Related Products	*1*	-	*1*	*1*
Timber Processing, Wood, Bamboo, Cane, Palm Fiber and Straw Products	*2*	*2*	*5*	*8*
Furniture Manufacture	-	-	-	-
Paper Making and Paper Products	*42*	*53*	*128*	*83*
Petroleum Processing, Coking and Nuclear Fuel Processing	*21*	*17*	-	*1*
Raw Chemical Materials and Chemical Products	*45*	*26*	*30*	*23*
Chemical Fiber	*3*	*3*	*1*	-
Rubber Products	*6*	*3*	*2*	*3*
Plastic Products	*8*	*5*	*4*	*8*
Nonmetal Mineral Products	*195*	*202*	*287*	*281*
Smelting and Pressing of ferrous Metals	*12*	*34*	*40*	*26*
Smelting and Pressing of Non-ferrous Metals	*28*	*12*	*13*	*14*
Metal Products	*1*	*1*	*1*	*2*
Electric Equipment and Machinery	*1*	-	*1*	*1*
Electronic and Telecommunications Equipment	*1*	-	-	*1*

Sources: *Guangdong Statistical Yearbook*, various years.

Note: "-" denotes coal consumption that is negligible.

> Manufacture's consumption of coal in Guangdong in 2003 was 2/3 that of the power sector. Manufacture's use of coal is also rising, with a 20% increase between 2000 and 2004. (Table 3)

In 2004 in Guangdong, 'Nonmetal Mineral Products' had the largest sub-sectoral direct consumption of coal at 13.5 million tons, up from 10 million tons in 2000.[25] The next largest sub-sectoral consumer of coal in 2004, 'Paper Making and Paper Products' consumed just under 4 million tons, up from 2.5 million tons in 2000. *Direct consumption of coal in the 'Textile' sub-sector was 3.3 million tons in 2004 compared to 1.0 million tons in 2000, a 330% increase in just 4 years.*

Yet, a number of significant users of coal seem to be moving away from it. 'Food Processing' consumed 2.8 million tons in 2004 (down from 4.5 million tons in 2000), 'Smelting and Pressing Ferrous Metals' 1.2 million (down from 1.6 million tons in 2000) and 'Raw Chemical Materials' 1.1 million tons, (down from 1.2 million tons in 2000).[26]

> The picture for direct manufacture's use of coal in Guangdong is changing quickly with some sub-sectors switching heavily towards coal (e.g., 'Non-mineral Products' up 60% in 4 years, 'Textile' up 330%, and 'Rubber Products' up 15%). Meanwhile, other sub-sectors, such as 'Food Processing', 'Smelting and Pressing Ferrous Metals', and 'Raw Chemical Materials' are moving away from coal.

[25] Bureau of Statistics of Guangdong Province, various years, op.cit.
[26] Ibid.

Fuel Oil and Diesel Fuel

We were unable to obtain sub-sector breakdowns for manufacture's use of fuel oil and diesel fuel. Nonetheless, we can say that officially in 2003 manufacturing in Guangdong consumed 205 PJ of fuel oil. This is up substantially from the level of 138 PJ reported for 2002. If accurate, it would indicate nearly a 50% increase in one single year. (See Appendices IV and V)

For diesel fuel the picture was similar, if not so dramatic. In 2003 consumption of diesel fuel by manufacturing was 152 PJ in 2003 compared to 128 PJ in 2002 (a 19% increase).

> In 2003 manufacturing in Guangdong consumed 78% as much fuel oil as did public power generation, and 90% as much diesel fuel as that consumed by transport.

In 2003 the industrial energy end-uses in Guangdong by fuel types were: coal (52%), fuel oil (17%), diesel fuel (13%), other petroleum products (12%), LPG (3%), and refinery gas (3%). Compared to 2002, the relative share for fuel oil and coal for industrial energy end-uses were both up somewhat, while the share for diesel fuel was slightly lower. (See Appendices IV and V for industrial energy end-use data in PJ)

Energy Use in Major Cities

Guangzhou

There are roughly 5,000 Hong Kong-based manufacturing establishments in Guangzhou.[27] In 2003 reported 'Manufacturing' energy use was coal 32PJ, fuel oil 35 PJ, and diesel 10 PJ. The largest coal consuming manufacturing sub-sector was 'Paper Making and Paper Products' (19 PJ), followed by 'Smelting and Pressing Non-ferrous Metals' (12 PJ), the 'Textile' industry (11 PJ) and 'Raw

[27] Federation of Hong Kong Industries, op.cit.

Chemical Materials and Chemical Products' (11 PJ). In 1999 it was 'Agricultural and Sub-line Products' (17 PJ) which led coal consumption among manufactures, while 'Textile' (<3 PJ) consumed relatively little coal.[28]

It should be noted that public power generation remains by far the largest user of coal in Guangzhou with 222 PJ used in 2003.

> Broadly speaking, manufacture's use of coal in Guangzhou has been falling somewhat but certain sub-sectors have been experiencing substantial growth rates, including 'Textile', 'Smelting and Pressing of Non Ferrous Metals', and 'Paper Making'.

Direct manufacture's use of fuel oil in Guangzhou in 2003 was reported to be 35 PJ. This compares to 57 PJ used for public power generation in Guangzhou. Of the direct use of fuel oil by local manufacturing 41% (14.5 PJ) was for the 'Petroleum Processing, Coking and Nuclear Fuel Processing' sub-sector. The next largest user of fuel oil was 'Chemical Materials and Chemical Products' (8 PJ), 'Textile' (2.4 PJ), and 'Smelting and Pressing of Ferrous Metals' (2.1 PJ). In 1999 'Textile' led in Guangzhou's manufacturing fuel oil consumption (3 PJ).

For diesel fuel 'Plastic Products' led in consumption (2 PJ) followed by 'Leather, Furs, Down, and Headgear Manufacturing', 'Food Production', 'Textile' and 'Raw Chemical Materials and Chemical Products' (each between 0.7 and 0.9 PJ). In 2003 1.7 PJ of diesel fuel use was reported for public power generation.[29]

> Fuel oil consumption by Guangzhou's industry (excluding petroleum processing) has been relatively steady. In 1999 it was 20 PJ and in 2003 it was 21 PJ.

[28] Statistics Bureau of Guangzhou Municipality, *Guangzhou Statistical Yearbook*, various years, China Statistics Press, Beijing.
[29] Ibid.

> However, for the 'Petroleum Refining Coking, and Nuclear Fuel Processing' sub-sector consumption of fuel oil rose from 3 PJ in 1999 to 14.5 PJ in 2003 – a 500% increase in only 4 years; a truly staggering annual average rate of 71% per year!
>
> The next largest sub-sectoral user of fuel oil, 'Raw Chemicals and Chemical Products' consumed about 8PJ in 2003, a level more than double its 1999 level. However, 'Textile' saw a drop in its use of fuel oil from 3PJ to 2.4 PJ over the same period.

Shenzhen

There are close to 16,000 Hong Kong-based manufacturing establishments in Shenzhen.[30] For 2003 Shenzhen reported manufacture's coal consumption of 31 PJ. This level accounted for 41% of energy use considering direct manufacture's consumption of coal, fuel oil and diesel fuel combined. Nearly all of the reported manufacture's coal use was in the 'Ordinary Machinery' sub-sector. Nonetheless, direct manufacture's use of coal is dwarfed by the 61 PJ used for public power generation there.[31]

Reported manufacture's fuel oil use in the city for 2003 was 25 PJ. This amount is again dwarfed by the 67 PJ of fuel oil used for public power generation. The largest manufacturing consumers of fuel oil were 'Ordinary Machinery' (13 PJ), 'Textile' and 'Nonmetal Mineral Products' (both between 3.6 and 3.9 PJ). In 1999 'Nonmetal Mineral Products' and 'Textile' had led in fuel oil consumption (both close to 4.1 PJ). [32]

Of the 20 PJ of diesel fuel used in 2003 in Shenzhen the largest consumers were 'Electronic and Telecommunications Equipment' (3.7 PJ), followed by 'Plastic

[30] Federation of Hong Kong Industries, op.cit.
[31] Statistics Bureau of Shenzhen Municipality, *Shenzhen Statistical Yearbook*, various years, China Statistics Press, Beijing.
[32] Ibid.

Products' (2.5 PJ), and 'Electric Equipment and Machinery' (2.4 PJ). Interestingly, public power generation still accounted for 13 PJ of diesel fuel use in Shenzhen in 2003 (down from about 21 PJ in 1999).[33]

> Compared to Guangzhou, Shenzhen relies much less on coal and reported coal use is highly concentrated in a single sub-sector ('Ordinary Machinery'). The relative share of fuel oil and diesel fuel are also more closely matched than in Guangzhou where diesel fuel plays only a relatively modest role.

<u>Dongguan</u>

Dongguan is the most popular location for Hong Kong-based firms operating manufacturing facilities in Guangdong with more than 18,000 plants.[34] We were not able to obtain data comparable to that for Guangzhou and Shenzhen for Dongguan. However, it is reported that direct manufacture's consumption of coal in 2003 in Dongguan was 74 PJ.[35] Major sub-sectoral users of coal include 'Papermaking and Paper Products' (28 PJ), and 'Farm and Sideline Food Processing' (17 PJ). As with Shenzhen and Guangzhou, it is the public power generation that accounts for the lion's share of coal consumption with 211 PJ in 2003.[36]

The only reported sub-sector use of fuel oil for Dongguan in 2003 was the 'Textile Industry' at 7 PJ. This compares to 41 PJ of fuel oil used for public power generation. For diesel fuel use the total in Dongguan in 2003 was 26 PJ, with information on three sub-sectors given: 'Telecommunications, Computers and Other Electronic Equipment Manufacturing' (5 PJ), 'Textile Garments Footwear and Headgear Manufacturing' (4 PJ) and 'Plastic Products' (3 PJ).[37]

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[33] Ibid.
[34] Federation of Hong Kong Industries, op.cit.
[35] Dongguan Statistics Bureau. See http://www.dgs.gov.cn/dgsweb/tjzl/200433.htm
[36] Ibid.
[37] Ibid.

The Broader Energy Supply Picture

In a companion piece to this report, Loh reviewed the larger picture for energy supply in Guangdong and China.[38] Here, we note a number of specific points that help put the demand for energy in Guangdong in context.

China has only 2% of the world's proven oil reserves and yet has a very high and rapidly growing demand. In 2003 China became the third largest oil importer in the world (after the United States and Japan) and has become the second largest oil consumer (after the United States). If the personal car industry in the Mainland continues to grow rapidly China's oil demand would literally change the face of world oil consumption. The picture for natural gas is even less bright. China has less than 1% of world natural gas reserves, but hopes to meet up to 10% of its energy needs by 2020 (up from 3% in 2003) from natural gas (largely via imports of LNG).

The rapid growth of China's oil consumption has strained the nation's refining capacity, particularly with respect to the ability to produce oil products of relatively low sulphur content so as to contribute to reduced emissions. Questions remain as to whether the supply from the major state-owned refineries (Sinopec and PetroChina) of low sulphur diesel fuel would be adequate to meet demand. If not, as seems to be the case today, then any gap would likely be filled by small local private refineries which provide fuel of lower quality.

> As Loh mentions, suppliers and traders believe that as much as 40% of the oil products used in Guangdong today come from such non-official sources.

While Sinopec and PetroChina are expanding their refining capabilities and up-grading their refining processes to produce cleaner fuels, World Trade Organization (WTO) stipulations mean that by the end of 2006 foreign oil companies will be allowed to distribute wholesale imported petroleum crude

[38] Loh, op.cit.

and products.[39] Oil *imports* (via the state-owned oil companies) are already a major part of the Guangdong energy picture. In 2003 provincial petroleum refiners produced 103 PJ of fuel oil, while a net of 431 PJ were imported from overseas. A net of 14 PJ was sent from Guangdong to other provinces (See Appendix IV).

LPG was also largely imported. In 2003 209 PJ of LPG was imported from abroad compared to provincial refinery output of only 22 PJ and sending out to other provinces of 141 PJ. In other words, 90% of LPG is imported but over 60% of LPG is sent onto other provinces (Appendix IV).

However with diesel fuel imports play a much smaller role. Net imports of diesel fuel are only 17 PJ compared to refinery output of 306 PJ (Appendix IV). At the time of this writing (March 2006) there are no natural gas imports into Guangdong. But starting in the second half of 2006 this will change with the operation of Guangdong's first LNG terminal. Initially the terminal will have a capacity of 3.7 million tons of LNG (0.19 PJ) and then rising to 10 million tons (0.5 PJ) in 2008.[40] The LNG imports will come from Australia.

> A key feature of the energy situation in Guangdong (and indeed throughout China) is the state controls on prices. The basic problem is that while the importers must pay international prices (which rose significantly in 2005) authorities have not allowed the full effect of the higher fuel costs to be reflected in the prices paid by consumers for oil products.
>
> In late 2005 the distortion was so severe that *Sinopec* requested and received from the central government RMB¥ 10 billion in compensation.

[39] Ibid.

[40] Visit http://www.cnoocgp.com/servlet/Page?Node=1323 for more information about the LNG terminal.

Limiting the impact of high oil prices on consumers clearly has an appeal. It restrains cost increases for manufacturing, while sheltering the poor from cost increases that would reduce their purchasing power even further. Yet price controls, however well intentioned, distort the incentives faced by buyers, whether they be manufacturing establishments or individuals. When the price of something is relatively low, buyers have less incentive to use the item efficiently. And when the use of that product causes pollution, lower efficiency means higher pollutant emissions. If oil product prices were allowed to rise, buyers would have stronger incentives to improve things like combustion efficiency (whether in a factory heating system or a home appliance). They would also tend to look for ways to reduce their overall energy requirements (for example in manufacturing by modifying the plant's production system, or adding insulation on heat transfer pipes).

Conclusion

The problem of addressing manufacturing air pollution in Guangdong is a difficult one. *Even if there is a willingness* on the part of industrial fuel users to pay more for higher quality fuel, or on the part of the authorities to impose requirements for its use, at present cleaner fuels are not readily available and are unlikely to come to the market until price controls are relaxed.

As noted above, things should improve – to at least a moderate degree – by 2008 when the public power system is expected to have adequate generation capacity to meet most manufacturing needs. This should substantially cut back on manufacturing self power generation through the use of small diesel and fuel oil driven private power generators. In other words, unless such reductions are offset by expansion of the manufacturing base, manufacture's use of diesel fuel and fuel oil in Guangdong should fall in the coming few years.

The coming liberalization of fuel supplies under the WTO, expanded domestic reining capacity to produce cleaner fuels, and (hopefully) the gradual reform of fuel price controls will provide a crucial opportunity to broadly improve fuel quality and to impose an outright ban on the most polluting fuels (higher sulphur coal and fuel oil), or if their continued use is permitted, only on condition of employing FGD and other stack gas emission controls. Our point here is not that one can simply assume that such moves will occur, but rather, that the switch to cleaner fuels will become much more practical than it is at present.

> Another positive change in southern Guangdong will be the development of 4 clean and highly efficient natural gas-fired power plants with a generation capacity of 4.2 GW.
>
> In the longer term, if the requisite LNG supplies can be attained at an acceptable price, it would be possible to build a relatively short distribution network to provide gas to industrial estates in southeast Guangdong.
>
> Such a move, especially if coupled with government requirements to use the gas as feasible in place of liquid fuels has the potential to make manufacturing output in the eastern PRD much less of an environmental threat to all of us than it is today.

Yet, despite rays of hope, one must recognize that prospects are not particularly bright.

- *First,* coal will remain the major source of power generation in Guangdong for some time to come;

- *Second,* those sub-sectors relying on coal or heavy fuel oil are likely to continue to self-generate because it is cheaper;

- *Third*, constraints on public power supply are not only ones of generation capacity, but in some case of transmission capacity;

- *Fourth,* in order to initiate a widespread clean-up higher quality fuels must be readily available in Guangdong, and this is unlikely to happen until price controls are eased;

- *Fifth,* higher energy prices are providing an incentive for manufacture to switch to cheaper dirtier fuels;

- *Sixth*, there must be either sanctions or a willingness to 'come clean' on the part of industries in Guangdong. Given our experience, we see little hope in voluntary measures beyond a feel good factor; and

- *Finally*, we must reduce manufacturing emissions before we face the *combined effects* of high manufacturing emissions and emissions from an exponentially expanded Guangdong motor vehicle fleet.

Recommendations

1. The Hong Kong Government should be explicit in stating Hong Kong has a direct interest in Guangdong's energy use and looks forward to:

- Lifting price controls on petroleum products.

- Discouraging (and as appropriate *banning*) high sulphur fuel oil for any industrial purpose once supplies become more flexible.

- Eliminating use of diesel fuel above 0.5% sulphur for *any* purpose and move gradually toward much lower sulphur content (e.g., < 0.05%).

- Considering the major role of coal, ban the use of coal with sulphur content above 1.5% and as feasible require the use of fuel gas desulphurization and other stack gas emission controls such as electrostatic precipitators.

2. The Hong Kong Government should work with Hong Kong-owned manufacturing establishments in the PRD to:

- Invest in energy efficient equipment and processes.

3. Hong Kong's business associations with members who own and manage factories in Guangdong should:

- Work to raise awareness among their members about responsibility toward reducing the Territory's 'imports' of air pollution from across the border.

- Encourage energy auditing for larger manufacturers (to help reduce energy costs and emissions).

4. Hong Kong manufacturing establishments in Guangdong should:

- Take the lead in energy conservation.

- As cleaner fuels become available, pledge to use the cleanest fuel.

APPENDIX I

The Pearl River Delta Industrial Fuel Use Survey
Questionnaire

We would like to ask you a few questions and to listen to ideas and comments you may have on the topics we raised. **All responses will remain anonymous.**

1. Self Power Generation

If you have your own generators:

(a) Why do you self-generate?

(b) What is the capacity (kilowatts) and typical annual output (kilowatt hours) of your own generators?

(c) What grade of diesel fuel/fuel oil do you use in your generators?

(d) Why do you use that particular grade of fuel?

(e) What is your operating efficiency (litres/kWh)

(f) Very approximately, what percentage of your annual *VARIABLE COSTS* is accounted for by purchases of fuel for your own generators?

(g) Is there something else that is important for your decisions regarding self-generation and fuel choice for those generators?

2. Energy for Process Heat

If you require substantial amounts of process heat for your operations:

(a) Please briefly describe the process and indicate any basic requirements, such as steam, hot water, highest temperature, uniformity of temperature.

(b) What type of equipment do you use to generate your process heat (small steam plant, hot water boilers)?

(c) What grade of fuel do you use to meet these process heat needs?

(d) Why do you use that particular grade of fuel for process heat?

(e) Roughly, how much fuel do you use for process heat in a typical year?

(f) Very approximately, what percentage of your annual *VARIABLE COSTS* is accounted for by purchases of fuel for making process heat?

(g) Is there something else that is important for your decisions regarding the type of fuel you use to make process heat?

Do you have any other comments, suggestions with regard to practical options for reducing air pollutant emissions from your operation and those of neighbouring production facilities?

– end of questionnaire –

APPENDIX II

Fuel Samples Analysis Results

Sample Reference Number	Fuel Type	Analysis Results								
		Sulphur Content	Unit	Method	Water Content	Unit	Method	Viscosity	Unit	Method
2005-MIS-023943-001	180# Fuel Oil	2.56	wt%	ASTM D4294-03	0.9	Vol %	ASTM D95-99	181.7	cSt	ASTM D445-04 @ 50°C
2005-MIS-023940-001	0# Diesel (Black)	0.964	wt%	ASTM D4294-03	0.017	wt %	Karl Fischer	6.119	cSt	ASTM D445-04 @ 20°C
2005-MIS-023940-002	0# Diesel (Light)	0.0813	wt%	ASTM D4294-03	0.012	wt %	Karl Fischer	4.467	cSt	ASTM D445-04 @ 20°C
2005-MIS-023940-003	0# Diesel	0.302	wt%	ASTM D4294-03	0.026	wt %	Karl Fischer	3.155	cSt	ASTM D445-04 @ 20°C
2005-MIS-023940-004	0# Diesel	0.256	wt%	ASTM D4294-03	0.02	wt %	Karl Fischer	4.436	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-001	0# Diesel	0.184	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	4.673	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-002	0# Diesel	1.36	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	7.207	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-003	0# Diesel	0.454	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	5.054	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-004	0# Diesel	0.155	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	4.938	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-005	0# Diesel	0.172	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	6.08	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-006	Industrial Diesel oil	0.415	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	5.684	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-007	Boiler Diesel Oil	0.495	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	6.646	cSt	ASTM D445-04 @ 20°C
2006-MIS-001988-008	Industrial Diesel oil	0.411	wt%	ASTM D4294-03	<0.05	Vol %	ASTM D95-99	6.494	cSt	ASTM D445-04 @ 20°C

Note: cSt stands for centistokes

APPENDIX III

Industrial Consumption of Public Electricity Power in Guangdong (in GWh), 1998 to 2004.

	1998	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
Industry Total Consumption	**62969**	**69566**	**87892**	**96218**	**112747**	**136884**	**164807**
1. Mining and Quarrying	**1672**	**1719**	**1870**	**1982**	**2492**	**1511**	**1834**
Coal Mining and Dressing	454	327	245	311	297	168	188
Petroleum and Natural Gas Extraction	332	51	37	39	372	576	777
Ferrous Metals Mining and Dressing	68	71	85	90	98	114	139
Nonferrous Metals Mining and Dressing	234	238	248	293	304	283	297
Nonmetal Minerals Mining and Dressing	483	922	1086	1071	1206	369	433
Other Minerals Mining and Dressing	51	36	61	60	83	1	0
Logging and Transport of Wood and Bamboo	50	74	108	118	132	0	0
2. Manufacturing	**45425**	**50199**	**63957**	**71578**	**84506**	**90834**	**114815**
Food Processing	1815	1974	2721	2323	2529	2450	3174
Foods Production	944	766	1249	958	869	1326	1588
Beverage Production	414	531	674	580	515	782	901
Tobacco Products	78	116	150	153	74	105	262
Textile Industry	2946	3457	4207	4786	5572	5524	6375
Garments and Other Products	1196	1321	1837	2094	1965	2988	3117
Leather, Furs, Down and Related Products	655	782	1044	1154	1401	2202	2742
Timber Processing, Wood, Bamboo, Cane, Palm Fiber and Straw Products	277	355	390	452	449	695	977
Furniture Manufacture	144	215	252	374	487	1007	1470
Paper Making and Paper Products	2203	2414	2992	3520	3903	4886	6043
Printing and Record Medium Reproduction	268	340	439	592	728	1181	1459
Cultural, Educational and Sport Articles	830	960	1154	1333	1500	2292	2777
Petroleum Processing, Coking and Nuclear Fuel Processing	980	1094	2067	1928	1416	1749	2152
Raw Chemical Materials and Chemical Products	2786	2819	3058	3134	3609	5983	7269
Medical and Pharmaceutical Products	470	426	444	416	518	731	924
Chemical Fiber	972	1081	1142	1195	1346	565	651
Rubber Products	2318	2381	3955	4631	4830	746	1184
Plastic Products	2980	3001	2961	3675	4977	6524	8186
Nonmetal Mineral Products	7517	8196	10089	10798	12276	13542	14481
Smelting and Pressing of ferrous Metals	2137	2290	2686	2590	2972	5456	5937
Smelting and Pressing of Non-ferrous Metals	698	641	868	986	1261	1971	2664
Metal Products	3148	3791	5367	6499	8003	4106	5678
Ordinary Machinery	1335	1752	2120	2178	797	1612	1951
Equipment for Special Purposes	251	260	288	295	381	885	1868
Transportation Equipment	622	651	907	966	2058	1767	3156
Electric Equipment and Machinery	1699	1759	2932	2941	3556	6186	8407
Electronic and Telecommunications Equipment	2195	2910	3980	4979	6056	11019	16090
Instruments, Meters, Cultural and Office Machinery	332	410	412	527	601	1393	1809
Other Manufacturing Industry	3213	3496	3568	5521	9857	1161	1523
3. Electric Power, Gas and Water Production and Supply	**15872**	**17648**	**22065**	**22658**	**25749**	**44539**	**48158**
Electric Power, Steam & Hot Water Production & Supply	13833	15398	19701	20209	22962	41979	44987
Gas Production and Supply	172	188	225	192	201	74	93
Tap Water Production and Supply	1867	2062	2139	2257	2586	2486	3078

Sources: *Guangdong Statistical Yearbook*, various years.

APPENDIX IV

Guangdong's Energy Balance Sheet 2003 (in PetaJoule 10^{15}J)

Items	Total Coal [a]	Coke[b]	Other Coal Gas[c]	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Cokes Oven Gas	Natural Gas	Other Petroleum Products	Heat Power	Electricity	Other Energy
1. Total Primary Energy Supply	**1658**	**49**	**38**	**876**	**2**	**-18**	**94**	**416**	**182**			**5**	**-5**		**221**	**28**
1.1 Indigenous Production	140			533								106			172	
1.2 Recovery of Energy			38													28
1.3 Moving In from Other Province	1522	67			115	4	151	127	40						77	
1.4 Import	23	16		609		5	17	433	209				84		11	
1.5 Chinese Airplanes & Ships in Refueling Abroad						8										
1.6 Sending Out to Other Provinces (-)		-28		-249	-103	-30	-79	-141	-66			-36	-86		-1	
1.7 Export (-)	-26	0			-9	-5	-10	-2	-1			-66	-6		-38	
1.8 Foreign Airplanes & Ships in Refueling in China						-1										
1.9 Stock Change	-2	-6		-17	-2	2	14	-1	1				2			
2. Input (-) & Output (+) of Transformation	**-1000**	**16**	**5**	**-864**	**160**	**69**	**292**	**-182**	**42**	**30**	**3**		**143**	**56**	**510**	**-28**
2.1 Thermal Power	-939		-5	-3	0		-14	-262		-1			-5		510	-27
2.2 Heating Supply	-42		-2				0	-21	0	-2			-13	56		0
2.3 Coal Washing	5															
2.4 Coking	-20	16									3					
2.5 Prtroleum Refiners				-862	160	69	306	103	44	34			161			
2.6 Gas Works	-3	0	12					-2	-2	-1						
3. Loss	**3**			**4**	**0**	**0**	**1**	**1**							**73**	

To be continued ……

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Items	Total Coal [a]	Coke[b]	Other Coal Gas[c]	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Cokes Oven Gas	Natural Gas	Other Petroleum Products	Heat Power	Electricity	Other Energy
4. Total Final Consumption	**656**	**65**	**43**	**8**	**161**	**51**	**385**	**233**	**225**	**30**	**3**	**5**	**138**	**56**	**658**	
4.1 Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy	11				6		39								11	
4.2 Industry	627	65	28	8	11	2	152	205	46	30	3	5	138	56	419	
4.3 Construction	0				3		7								10	
4.4 Transportation, Storage, Postal & Telecommunications Services	0				101	49	169	25							18	
4.5 Wholesale, Retail Trade and Catering Service	4		4		9		13	3	7						53	
4.6 Residential Consumption	14		11		22	1	3		172						93	
4.7 Others					9		2								54	
5. Statistical Difference [d]																

Source: *China Energy Statistical Yearbook 2004*.

Notes: (a) Coal Total = Raw Coal + Cleaned Coal + Other Washed Coal + Briquettes

(b) Coke = Coke + Other Coke Products

(c) Other Coal Gas may include Gas Furnace, Heavy Oil Catalytic Cracking, Heavy Oil Thermal Cracking, Coke Gas, Pressure Gasification and Water Coal Gas, which is assumed with an average heat value of 1.697 PJ/10^8cu.m

(d) Statistical Difference = Total Primary Energy Supply + Input (-) & Output (+) of Transformation – Loss –Total Final Consumption

APPENDIX V

Guangdong's Energy Balance Sheet 2002 (in PetaJoule 10^{15}J)

Items	Coal Total[a]	Coke	Other Coal Gas[c]	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Natural Gas	Other Petroleum Products[d]	Heat Power	Electricity	Other Energy
1. Total Primary Energy Supply	**1395**	**35**	**30**	**820**	**-5**	**-25**	**69**	**407**	**160**			**-27**		**164**	24
1.1 Indigenous Production	46			529							123			136	
1.2 Recovery of Energy			30												24
1.3 Moving In from Other Province	1388	47			97	0	134	112	16					57	
1.4 Import	7			527		2	6	345	200			138		8	0
1.5 Chinese Airplanes & Ships in Refueling Abroad						7									
1.6 Sending Out to Other Provinces (-)	0	-9		-228	-101	-28	-62	-55	-58		-21	-97		0	
1.7 Export (-)	-18	-3		-7		-6	-5				-102	-68		-37	0
1.8 Foreign Airplanes & Ships in Refueling in China		-3				-1									
1.9 Stock Change	-28	3		1	-1	0	-3	4	3			-1			
2. Input (-) & Output (+) of Transformation	**-924**	**15**	**6**	**-813**	**154**	**69**	**261**	**241**	**35**	**31**		**139**	**56**	**443**	−21
2.1 Thermal Power	-862		-4	-2	0		-31	293	0	-1		-3		443	−23
2.2 Heating Supply	-39		-2				0	-22		-2		-10	56		0
2.3 Coal Washing	-20	16													3
2.4 Coking				-810	154	69	292	76	36	34		153			
2.5 Prtroleum Refiners	-4	-1	12				0	-1	-2	0					
2.6 Gas Works	0														
3. Loss	**2**			**3**	**0**	**0**	**1**	**1**						**44**	

To be continued ……

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Items	Total Coal [a]	Coke [b]	Other Coal Gas [c]	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	LPG	Refinery Gas	Natural Gas	Other Petroleum Products	Heat Power	Electricity	Other Energy
4. Total Final Consumption	**468**	**50**	**37**	**5**	**148**	**44**	**330**	**165**	**195**	**31**		**112**	**56**	**563**	3
4.1 Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy	10				6		38					2		17	
4.2 Industry	437	50	23	5	10	1	128	138	38	31		110	56	361	3
4.3 Construction	0				3		5							9	
4.4 Transportation, Storage, Postal & Telecommunications Services	0				95	42	144	25						10	
4.5 Wholesale, Retail Trade and Catering Service	3		4		8		10	2	6					46	
4.6 Residential Consumption	17		10		19	1	3		151					84	
4.7 Others					8		2							35	
5. Statistical Difference [b]															

Source: *China Energy Statistical Yearbook* (2000-2002)

Notes: (a) Coal Total = Raw Coal + Cleaned Coal + Other Washed Coal + Briquettes

(b) Statistical Difference = Total Primary Energy Supply + Input (-) & Output (+) of Transformation – Loss – Total Final Consumption

(c) Other Coal Gas may include Gas Furnace, Heavy Oil Catalytic Cracking, Heavy Oil Thermal Cracking, Coke Gas, Pressure Gasification and Water Coal Gas, which is assumed with an average heat value of 1.697 PJ/10^8cu.m

(d) Heat value of Other Petroleum Products is calculated with 0.41816 PJ/10^4ton

(e) During converting units (10^4ton or 10^8cu.m into PJ) and calculation, there may exist a difference of 1 PJ over some data

(f) 1 Kg coal equivalence (Kgce) = 29271 KJ(7000Kcal)