Managing air quality in a rapidly developing nation -- China

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Abstract

As the world gets ready to begin the second decade of the Twenty-first Century, global climate change has been recognized as a real threat to civilization as we know it. The rapid and successful economic growth of developing nations, particularly China and India, is contributing to climate change. The route to initial economic success in China followed that of the developed nations through the development of industries. Unfortunately, China’s environmental protection efforts have not been the same as in developed countries because China is vastly different culturally, socially, economically and, especially, politically from developed nations. When China started to deal with environmental concerns in the late 1970s, it took advantage of the experiences of other countries in establishing environmental standards and regulations, but it did not have a model to follow when it came to implementing these standards and regulations because of the abovementioned differences. Economically, China is transitioning from an agricultural base into an industrial base; however, even now, 60% of the population remains farmers. China has been and still is heavily dependent upon coal for energy, resulting in serious atmospheric particu-
late pollution. While growing efforts have been expended on the environment, at this juncture of its economic development, China would be well served to revisit the traditional “develop first and cleanup later” approach and to find a balance between development and protecting the environment. Against this backdrop, a reflective look of the effort to manage air quality from 1949-2008 (with an emphasis on the past 30 years) in China is presented in this paper. The environmental component of the 2008 Olympic Games is examined as a special example to illustrate the current measures being used to improve air quality in China.

**Keywords:** Air pollution, air quality, economic growth, energy, coal, Olympic Games, China

1. Introduction

In the last decade, China reported an increase of 1.2 °C in average temperatures after 30 years of constant temperatures from 1950 to 1980. This increase in temperature could be a hint that China is experiencing the effects of global warming (Report on the State of the Environment in China (hereafter referred to as RSEC) 2006, 2007).

We previously published a review of air pollution research in China, which contains a detailed analysis of the state of the atmospheric environment in mega cities in China (Chan and Yao, 2008). The present paper considers air pollution problems in China (using particulates as an illustration) from a socio-economic and historical point of view that we believe will shed more light on the current situation in China. It is a complement to our earlier review. Air quality issues pertinent to the 2008 Beijing Summer Olympic Games are used as a case study.

1.1 Background
China is completing its third decade of economic development known as the “(Economic) Reform and Open (Door) Policy”, which started in 1978. Its gross domestic product (GDP) increased 57-fold from 362.4 billion RMB in 1978 to 20.94 trillion RMB (US$2.7 trillion) in 2006 (Fig. 1). At the same time, China gained the reputation of being the “manufacturing center for the world”. China has lifted millions of its people out of extreme poverty to a reasonable level of living standard, and, at the same time, it has provided low-cost and good-quality consumer products to the people all over the world. Unfortunately, the quality of its environment has deteriorated primarily because of the energy requirements for such development. China has become the target of numerous and continuous reports and criticisms, especially from the US media (e.g., NY Times, 26 Aug 2007) on its environmental problems. On a per capita basis, the US (20.4 metric tons of carbon dioxide emissions per capita, 2004) is a far greater contributor to global climate change, historically and currently; however, China (3.84 metric tons of carbon dioxide emissions per capita, 2004) is catching up at a speed that is as remarkable as its economic growth. China is probably the first developing nation that has received so much international pressure to curb its pollution. The 2008 Olympic Games has attracted much attention from the press because of concerns about the air quality in Beijing, even though the Games have a very substantial environmental component and half of the budget for the Games is allocated to making the Games green.

Writing a short summary on the history of atmospheric pollution of China is not an easy task given the broadness of the topic and the lack of available data. We therefore focus our discussion on the most recent 30 years. Only brief discussion is devoted to the period from 1958 to 1976 when social and political movements affected normal life in China.

Like any of the developed nations when they were developing, China’s air pollution resulted
from the close association between energy use and economic development. The approach to de-
velop first and then consider the environment is also similar. The problems were exacerbated in
China by the large population, the lack of capital, large-scale social movements and poor scien-
tific education among the general public. When the People’s Republic was founded in 1949,
China had just spent eight years defending itself against the Japanese in WWII and three years
fighting a Civil War, followed by the Korean War. China also faced a US-led full embargo from
1949 to 1969. Adding to this, the Great Leap Forward (an attempt to jump-start industrial devel-
opment and promote agricultural production in 1958-1960) and the Cultural Revolution (1966-
1976) that followed almost completely destroyed the economy. There is little wonder that as
China recovered from this series of events, national survival became its top priority and the
country’s full focus was on productivity. The approach of putting productivity ahead of envi-
ronmental protection was instituted at this time even though environmental disasters in Japan
were occurring on China’s doorstep.

1.2 Energy structure history

The National Environmental Protection Agency (NEPA) was formed in 1987 in China and
was upgraded to the State Environmental Protection Administration (SEPA, with ministerial
equivalence) in 1998. In March 2008, as a significant step towards improving the environment,
SEPA was elevated to the full ministry level (Ministry of Environmental Protection, MEP) so
that the commitment to clean up the environment made in the Eleventh Five-Year Plan could be
fulfilled. Not much air pollution monitoring, especially of particulates, was done prior to the
1970s. However, offshore sediments are partially formed by atmospheric depositions and the po-
lycyclic aromatic hydrocarbons (PAH) in core samples can give historic information on atmos-
pheric particulates emitted by combustion processes. Lima et al. (2003) and Liu et al. (2005) stu-
died such core samples in the Pearl River Delta and Guo et al. (2006, 2007) $^{210}$Pb-dated core samples extracted from the sediments in the East China Sea and off the estuary of the Yangtze River. Analysis of the PAH profiles gives a hint of the energy structure in China for the past 100 years.

As China was recovering from the wars in 1949, its rapid economic development began. The demand for energy increased accordingly. The first particulate peak came during the Great Leap Forward (1958-60) when millions of so-called “backyard furnaces” flourished all over China in an ill-fated attempt to produce the much-needed steel for the nation. $\text{SO}_2$ concentrations would also have peaked during this period.

During the Cultural Revolution, many manufacturing plants reduced their production, whereas population increases required more energy. As a result, a slow increase in energy use was observed. Two years after the official end of the Cultural Revolution, the “Reform and Open Policy” was introduced in 1978, moving China from a planned economy to one that is market driven; China entered the fastest industrialization (urbanization) period ever observed, first in the Pearl River Delta Region and later in the rest of the coastal regions of the country. The pace of industrialization has been sustained up to now. At the same time, deterioration of the environment accelerated. This vastly successful economic development model is often called by the Chinese the “Market-Driven Economy with Chinese Socialistic Features”; more plainly, it is a mixture of socialism and capitalism. Since air pollution is directly related to energy use, which in turn is closely associated with economic development, the accelerated economic development inevitably resulted in proportionally accelerated environmental deterioration.

The sediment core PAH analysis and energy statistics show that coal has been and still is the main energy source in China and its use has increased rapidly in recent years although petroleum
products are also increasing in use because of the growing transportation sector (Fig. 2). The change in the energy structure reflects the transformation from an agricultural economy to an industrial one.

The change in the energy structure in China in recent years follows that of developed nations: biomass → coal → petroleum products/nuclear energy → clean fuels (hydroelectricity and gas). The difference is that China started this transformation many decades later than the developed nations did and, furthermore, the transformation is being compressed into a much shorter time scale.

The distribution of energy use in China is coal = 68.9%, petroleum = 21.0%, renewables and nuclear = 7.2%, and natural gas = 2.9%; the corresponding numbers for the US are 22.8%, 39.7%, 13.9% and 23.5%. Coal provides 75% of electric power, 60% of chemical industry fuel, and 80% of the industrial fuel in China (CEFAPUCUS, 2007).

As the manufacturing center for the world, China’s economic growth is dependent on labor-intensive and resource-intensive manufacturing processes, although the high-technology industry is under rapid development (Streets et al., 2006). As the industrial development focuses more on knowledge and technology-intensive production, pollution will be reduced, the value-added will be larger, people will be better educated, and a concerted effort to protect the environment will become possible.

1.3 Atmospheric particulate pollution in the past

Compared with environmental protection in developed countries, which started in the 1950s, China only began to tackle its environmental problems in the late 1970s and atmospheric research began in the 1980s (CEFAPUCUS, 2007; Chan and Yao, 2008). China took advantage of the knowledge gained and accumulated by the developed countries to form a scientific frame-
work to formulate and promulgate standards and regulations, and many measures and actions were taken in the mid-1980s after the first peak in particulate concentrations was observed (He et al., 2002). The Environmental Protection Law of PRC (trial implementation) was adopted in September 1979, and, in September 1987, the Law on the Prevention and Control of Atmospheric Pollution was passed by the People’s Congress. It has been reported to be responsible for the slight reduction in the concentration of total suspended particulates (TSP) in that period (Florig et al., 2002; Nielsen and Ho, 2006). This law was revised for the first time in 1995 and later amended in 2002. In December 1989, the Environmental Protection Law was passed.

Visibility data were sometimes reported in lieu of TSP data before 1990. Qiu and Yang (2000) reported on visibility in northern Chinese cities from 1980 to 1994 and found low values in the mid-1980s. Wu et al. (2006) reported peaks in the number of hazy days (visibility <10 km and RH <80%) in southern Chinese cities in the mid-1980s and mid-1990s, respectively. The improved visibility between the two periods matched well with the soot and dust control measures taken on industrial and residential sources. Visibility data and measured aerosol optical depths also followed the trends in energy consumption, suggesting that there was another peak aerosol concentration in 1996 (Wu et al., 2006; Streets 2007).

Scientific exchange with the West started to flourish after 1978 and environmental protection was one of the topics of interest. In the last two decades, knowledge on atmospheric particulate pollution in China has improved considerably as funding for environmental research has increased (Florig et al., 2002; Chan and Yao, 2008). Hundreds of research papers have been published in international peer-reviewed journals and the literature is growing rapidly. China has made major efforts to reduce air pollutant emissions and to improve air quality across the country, including the increased use of renewable energy (hydroelectric projects such as the Three
Gorges Dam Project). Air quality monitoring systems were installed in over 200 cities and daily air pollution indices are now reported (RSEC 2006, 2007). Environmental protection legislation is reviewed and modified every five to ten years in conjunction with the national Five Years Plans (He et al., 2002).

2. Current status of atmospheric particulate pollution in China

Atmospheric particulates in China are complicated pollutants because of the large variations in sources, energy structures, climatic conditions and living habits across the nation (Feng et al., 2006, 2007). The particulates contain preexisting urban particulate pollution caused by coal combustion, “complex air pollution” and regional haze. The term “complex air pollution” emerged in the last decade. It is the consequence of mixing pollutants from coal combustion, vehicular emissions and perhaps biomass burning and it sometimes occurs on a city scale and other times on a regional scale (Shao et al., 2006). Some of these particulates have been reported to be transported to neighboring countries, the Pacific Ocean and North America (Brock et al., 2004; Goldstein et al., 2004). These particulates truly have global effects.

TSP, PM$_{10}$ and PM$_{2.5}$ are the major air pollutants in China. From 1990 to 1999, the annual average TSP concentration in 100 major cities decreased by ~30% to 256 $\mu$g m$^{-3}$ and it remained almost constant from 1999 to 2003 (Sinton et al., 2004), despite an overall decrease of 30% in total energy consumption from 1997 to 2002. PM$_{10}$ standards were added to the revised National Ambient Air Quality Standards (GB3095-96) in 1996, in addition to the TSP standards in the old version (GB3095-82). Before 2000, only TSP concentrations were reported; since then, PM$_{10}$ concentrations became available.

In 2006, only 4.3 % of the 559 cities monitored met the Grade-I standard (for natural reserves,
national parks and other protected areas) of GB3095-96 with annual PM$_{10}$ concentrations less than 40 µg m$^{-3}$, while 37.6% of the cities had greater than 100 µg m$^{-3}$ PM$_{10}$ concentrations (Grade-II standard, for urban residential, commerce-traffic-resident mixed, common industrial and rural areas), exceeding the World Health Organization Air Quality Guideline of 20 µg m$^{-3}$ (WHO, 2005). Florig (1997) estimated that air particulates caused one million premature deaths per year in China while the World Bank (1997) estimated that the damage caused by air and water pollution would be 3-7.7% of the GDP and would cause 300,000 premature deaths. The reliability of these estimates is debated in China, although the risk of contracting respiratory diseases caused by air pollution is widely accepted, although not much has been done to study the impact of air pollution on health in China.

The annual TSP concentrations in the northern cities are ~150 µg m$^{-3}$ higher than those in the southern cities due to space heating by coal burning, less rainfall and greater soil erosion. After 1997, annual TSP concentrations in the southern cities were within the Grade-II standard of 200 µg m$^{-3}$. The annual PM$_{10}$ concentrations in the southern cities are ~40 µg m$^{-3}$ less than those in the northern cities for the same reasons and they generally meet the Grade-II standards.

The annual PM$_{10}$ concentrations in major cities decreased from 121 µg m$^{-3}$ in 2003 to 100 µg m$^{-3}$ in 2005 (RSEC 2006, 2007) despite an increase in energy consumption although there are exceptions. Although in 1998 Beijing started its “phased intensive control program” to fight air pollution, PM$_{10}$ concentrations increased by ~10% from 2003 to 2006 because of the increase in coal-fired boiler emissions, construction activities and dust storms (UNEP, 2007). In addition, SO$_2$ emissions from residential coal-combustion in Beijing increased from 68,800 tons in 2003 to 85,100 tons in 2005 because of the expansion of the urban areas and this in turn increased the particulate sulfate concentration in PM$_{10}$.
PM$_{2.5}$ is not currently regulated in China but there have been a number of field studies in the last decade to quantify and characterize PM$_{2.5}$ (Chan and Yao, 2008). The chemical constituents in PM$_{2.5}$ and PM$_{10}$ across China are shown in Fig. 3. The major components include organic and elemental carbon, secondary inorganic ions (SO$_4^{2-}$, NO$_3^-$ and NH$_4^+$), and crustal species, such as Si, Al, Ca, and Mg. Carbonaceous particles and secondary inorganic ions accounted for more than 70% of the PM$_{2.5}$ mass in the eastern developed cities of Beijing, Nanjing, Shanghai, Guangzhou, Zhongshan, and Hong Kong while crustal species accounted for ~40% of the PM$_{10}$ mass in cities in central and western China.

In the spring, frequent dust storms in northwest China can severely impair visibility (Guo et al., 2004; Xie et al., 2005). Before the 1980s, haze occurred only in a few large cities (Wu et al., 2006). In the last decade, however, the occurrence of haze became more frequent and the scale became regional (Chan and Yao, 2008). As in many developed countries, haze in China is mainly due to secondary species (Sun et al., 2006; Xie et al., 2006). “Blue Sky” projects have been initiated in many cities to improve visibility. However, the results are less than desirable because haze does not respect city boundaries and regional efforts on the city and provincial levels is needed to address the problem.

2.1 Particulate pollution from coal burning

Between 1996 and 2000, coal consumption decreased from 1.51 to 1.28 billion tons before a drastic increase to 2.46 billion tons in 2006. However, concentrations of industrial and residential soot and non-combustion dust both decreased by ~50% from 1996 to 2006 (RSEC 2006, 2007). Industries consumed 94% of the coal, overwhelming residential consumption of 4%, while soot emissions from the latter was one-fifth of the industrial emissions in this period (Nielsen and Ho, 2006; China Statistical Yearbook 2006, 2007). This suggests that the abatement of primary parti-
culate emissions from industrial coal combustion was much more effective than from residential sources. It is estimated that primary industrial emissions accounted for only 15% of the TSP mass in most cities in China (Florig et al. 2002). The success in the control of soot emissions was due to the availability of low-cost dust control technologies for large industrial operations, such as power plants. However, control technologies for residential units are not affordable, especially when retrofitting old boilers. Most of them are not modified, although newly built residential units likely have effective emissions control or do not use coal at all. A great effort has been expended on replacing coal with natural or synthetic gas in the major cities for domestic use in the past three decades (CEFAPUCUS, 2007).

Particulate sulfate is the major inorganic ion in PM_{2.5} and PM_{10} in most cities because of the energy structure (Zhang et al., 2004; Yang et al., 2005; Chan and Yao, 2008). The control of SO_{2}, the precursor of sulfate, from combustion sources is not as cost-effective as the control of particulate emissions because desulfurization is a high-technology process compared to dust removal, which means that much more investment is required to reduce SO_{2} emissions. For example, in 2007, Fujian Province invested 60 million RMB and 270 million RMB to control particulates and SO_{2}, respectively, of two 600 megawatt power plants. The cost of controlling SO_{2} is over four times of controlling dust (http://guba.eastmoney.com/600388,8000108857,guba.html). If denitrification is also needed, the cost of installing such equipment becomes prohibitive in a developing nation like China. Only a few desulfurization units have been installed. China failed to achieve its control objective for SO_{2} in the past three years (RSEC 2006, 2007). Coal burning is also an important source of particulate organic pollutants in urban areas in China (Simoneit et al., 1991, Bi et al., 2003, Chen et al., 2005).

2.2 A new source of pollution -- vehicular emissions
In the past 30 years, China has transformed from a country dependent on bicycles for transportation to one of the world’s largest automobile producers. This certainly is good for the national economy but not necessarily good for the environment. The government actively encouraged the development of the automobile industry and private car ownership is no longer viewed as a bourgeois desire. A respectable network of highways and super-highways has been built and citizens in China are finally experiencing the same freedom to travel by private vehicles and rush hour traffic jams that are part of life in the West. The vehicular fleet increased by ~20% every year from 1990 to 2006 and this trend is likely to continue (He et al., 2002; RSEC 2006, 2007). The consequences of such prosperity and lifestyle changes are more pollution and related health issues, traffic accidents and premature deaths due to both pollution and such accidents.

On-road vehicle emissions is an important and perhaps the fastest growing source of atmospheric particulates in the mega cities in China (CEFAPUCUS, 2007; Chan and Yao, 2008). SEPA started to tighten vehicular emissions regulations 20 years ago. The first emissions regulations became effective in the 1993 (GB-14761). EURO-I standards for automobiles have been adopted and implemented since 2000, followed by EURO-II standards in 2004 and the production of EURO-I heavy-duty vehicles was terminated. In 2007, EURO-III standards were implemented to reduce vehicular emissions further. The more stringent EURO-IV standard will take effect in 2010. When compared to PM$_{2.5}$ concentrations in 1999-2000 in Beijing (He et al., 2001), PM$_{2.0}$ concentrations in 2003-2004 (Guinot et al., 2006) decreased by 8% while the automobile fleet increased in size from ~1.5 million in 2000 to ~2.3 million in 2004. The higher standards reduced CO concentrations and inhibited the increase in NO$_2$ concentrations in the mega cities in the past five years (Chan and Yao, 2008).
3. The atmospheric particulate control effort in China over the past 30 years

Over the past 30 years, through the efforts of MEP, environmental protection has begun to take shape in China and its effectiveness has been reviewed in a number of studies (He et al. 2002; Florig et al. 2002; CEFAPUCUS, 2007). Nonetheless, air pollution in China has become an international issue in this era of global concern about climate change and other environmental issues, suggesting that either not enough has been done or more needs to be done. The Health Effects Institute (HEI, 2004) compiled a list of knowledge deficiencies on the health impacts of air pollution in Asian countries including China. These included the role of poverty, the lack of long-term studies, and the roles played by indoor and outdoor air pollution. The lack of air pollution concentration-response functions over a large range of concentrations also hinders our understanding of the health impacts of air pollution. Perhaps a similar list can be compiled to allow a closer examination of the state of knowledge deficiencies specifically on the impacts of particulate pollution in China.

3.1 Fighting poverty hinders environmental protection

Ever since the introduction of the “Reform and Open Policy”, the disparity between the poor and the rich in China has grown wider by the day (Liu and Diamond, 2005). There were 35.5 million people still living in extreme poverty (annual income <US$130) in 2006 (China Statistical Yearbook 2006, 2007). Local officials usually prioritize economic productivity over environmental protection, as a rule, in an attempt to improve the lives of the poor. To attract investment, substandard factories and manufacturing plants are often allowed to operate. Such is the case for the coal mines in Shanxi Province, which gained international attention for many fatal accidents in recent years. The impetus for operating these privately owned and unsafe small mines is the rising price of coal in recent years. In addition to the fatal accidents, these mines are also pollu-
Biomass burning is practiced during harvest seasons by farmers to minimize outbreaks of pests and to replenish inorganic potassium to the soil. Although crop residue burning is banned, as long as fuel costs are an economic burden, this is very difficult to enforce.

3.2 Technology can help if the price is right

In China, most technologies used for controlling SO$_2$ and NOx (precursors of particulate sulfate and nitrate) are imported. Only large establishments such as large power plants can afford such technologies. In 2000, only seven power plants with MkW output were equipped with flue-gas desulfurizing equipment. This number increased to 45 in 2006, accounting for ~15% of the total number of coal-fired power plants (China Statistical Yearbook 2006, 2007). Again, economics is the issue. The prospects are good, however, because of the rapid economic development, the tightening of air pollution regulations and the increasing pressure from inside and outside of China. In retrospect, it would have been much cheaper to install such units when the power plants were built than to retrofit existing facilities, had the capital been available.

3.3 Energy efficiency – the roles of modern technology and management

The goal of the first outside investors (mostly from Hong Kong and Taiwan) in China was to take advantage of the low labor and land costs. They brought with them low-technology (labor-intensive and resource-intensive) processes and outdated equipment; in essence, the Hong Kong manufacturers reduced pollution in Hong Kong and moved it to China (mainly in the Pearl River Delta). This is why the later-developed Yangtze River Delta is more energy efficient than the Pearl River Delta, although the energy efficiency is still only ~1/10 that of the US and 1/5 that of Japan despite the decrease in primary energy consumption per RMB GDP from 0.45 kg of standard coal equivalent (SCE) to 0.15 kg SCE in 1999 to now (Sinton et al., 2004; RSEC 2006,
Further reducing primary energy consumption per GDP and upgrading production technologies and managerial skills are long-term measures to reduce pollution. In the period of 1992 to 2002, improvement in technology and efficiency has not kept up with the growth in consumption, leading to a net increase in production-related CO₂ emissions of 2,163 to 3,440 million metric tons (Peters et al., 2007). Reform of the industrial structure and development of high-value-added products are needed. Cooperation from developed countries in assisting in the development of low-polluting, high-technology industries is critical.

Many outdated technologies are still used in China. Just to mention the big energy consumers, 24.2% of the steel mills and 23.8% of the power plants (coal- and oil-fired) used antiquated technologies in 2006 (China Statistical Yearbook 2006, 2007). Adoption of cleaner production processes and/or better management will probably reduce some of the waste, but upgrading to state-of-the-art equipment has to be accelerated.

3.4 Planning and policies

In China, there are emissions standards to limit air pollutants emitted for various industries and a “total emission control” regulation has been implemented to limit the total air pollutant emissions in given air sheds since 2000. However, most efforts focus on urban areas, although 60% of the population lives in rural areas. As happened in the developed nations, urbanization moved city limits outward and has encroached lands that were once rural or in the countryside. At the same time, the rural areas surrounding big cities also began to prosper and expand both in size and economically; the result is the merging of urban and rural areas into mega cities. In the 1970s and 1980s, strong emissions sources (existing old factories) were relocated from within city limits to the countryside to make room for housing projects and land development and to get rid of the pollution. However, urbanization is affecting areas much larger than expected. What
used to be the countryside is now a part of the city, and the cities once again encircle the relocated pollution sources. In retrospect, relocating the polluting sources was effective in lowering the concentrations of primary gaseous pollutants in the cities but not those of particulate pollutants, certainly not secondary particles, fugitive dust and crustal materials.

4. A water-shed?

In his speech at the Olympic flame lighting ceremony on 24 March 2008 in Olympia, Greece, Jacques Rogge, President of the International Olympics Committee said, “The Beijing Games will not only be a moment of sporting excellence, but also an opportunity for the people of China and the world to learn, discover and respect each other.” Indeed, the Games have been venues for nations to show off their athletes and for the host nations to introduce their culture and national pride (especially important to developing nations) to the rest of the world. Since the adoption of the environmental factor in the 1994 Lillehammer Winter Games, having a good green proposal has been key to winning the right to host the Games. Beijing lost their initial bid to Sydney for the 2000 Games because of this. By design or by coincidence, the Games have become a proving ground for nations to test ideas and models for sustainable development because money for developing such models is relatively abundant, and the results receive high international media exposure. It is useful to use the 2008 Olympic Games as an example of what can be done for the environment in China although the scale is relatively small.

The 2008 Games venues are spread over six cities, although most of the Olympic’s environmental projects are concentrated in Beijing. As a rule, Beijing has been receiving the lion’s share of the national environmental protection budget. In 2006, the share given to Beijing was 10% of the full budget, even though Beijing accounted for less than 1% of the total air pollutant emis-
sions (Beijing Environmental Bulletin 2006, 2007; RSEC 2006, 2007). In total, US$12.2 billion (85.4 billion RMB) has been allocated so that Beijing can present a green Olympics to the world. How will the Chinese do this? More importantly, can China sustain the effort after the games? Will the Games fulfill its role as a catalyst for the green movement in China? Studies of the Mexico City, Los Angeles, Atlanta, Sydney and Athens games showed mixed results (Beyer 2006; Tian and Brimblecombe 2007). Sydney is the only city that benefited from this greening aspect of the Games.

To fulfill the air quality commitment made in the Olympic bid, Beijing and Tianjin (both are Olympic cities) and the surrounding provinces of Hebei, Shanxi, Shandong and the Inner Mongolia Autonomous Region formed an air pollution abatement region to minimize the transport of air pollutants to Beijing. This abatement region geographically covers a distance of 500-1000 km.

The Fourteenth Phase Intensive Control Program went into effect in early 2008 for the final preparation for the Games. SO$_2$, CO, NO$_2$ and respirable particulates were reduced by 60.8, 39.4, 10.8 and 17.8%, respectively from 1998 to 2007. The Beijing Olympics environmental project includes, in addition to air quality, green construction, water conservation, waste recycling, noise reduction, renewable energy, green maintenance of the infrastructure after the Games, etc. (http://www.bjepb.gov.cn/bjhb/portal0/default40.htm/). In this paper, we focus only on the air quality part of the project.

The Fourteenth Phase Intensive Control Program contains what is known as the “5655” strategy (http://www.bjee.org.cn/news/index.php?ID=19817). This is a comprehensive strategy to reduce atmospheric pollutants from combustion, crustal and construction sources. Table 1 contains the details of the strategy.

Some of the measures will start a couple of months before the Games. An odd-even day traf-
fic control scheme will be enforced to reduce traffic congestion and emissions, a measure that was demonstrated to be effective in Atlanta. These environmental measures are expected to be costly when all the investment, compensation and downtime are tallied up.

The most likely parts of the project to be retained are the education and the mass movement components. The people in the joint abatement region are being exposed to the concept of environmental protection and some of them are even participating in some of the conservation and protection programs. Perhaps they will learn to appreciate what can be done to improve the environment to improve their own living standards. Beijing’s Environmental Protection Bureau has indicated that the effort is not just for the Olympics. It is the Bureau’s intention to use the Games as a catalyst to keep the air in Beijing clean after the Games. It is optimistic that the air quality in Beijing will improve but continued efforts will be needed and it may take some time to achieve the goals (http://www.bjepb.gov.cn/bjhb/tabid/68/InfoID/10172/frtid/40/Default.aspx).

Certainly, government officials and leaders can and will learn first hand from the Games how to manage the environment under the watchful eye of the world. Data extracted and experience accrued will be very useful in helping them to develop policies, implementation plans and management schemes for even bigger projects for the whole nation. For example, some of the Olympic sites/venues in Beijing will be used for cultural, recreational and commercial use after the Games. This would allow the establishment of new communities on the Olympic sites with very good infrastructure and environmentally friendly buildings and facilities. Can this experience provide valuable insights to the planners and developers on how to resolve both traffic jams and air pollution that are experienced in most Chinese mega cities? Perhaps the establishment of these new communities will allow the planners to decentralize Beijing from the city planning point of view, and perhaps even go back to the old days (which is only some 30 years ago) when
most Chinese lived and worked within their self-sustained communities, and bicycles sufficed for daily transportation. It is possible that managing air quality is more effective when the management area is smaller.

5. Conclusion

As successful as China has been in the past 30 years in economic development, China is still a developing nation with the world’s largest population. China cannot begin to compare to the developed nations in terms of wealth and the distribution of wealth among its citizens (with a per capita GDP of US$2,460 compared US$46,780 in the US in 2006), social development, environmental protection awareness, and technology for production and for controlling pollution (http://www.imf.org/external/pubs/ft/weo/2007/02/weodata/index.aspx). Nonetheless, China can contribute to the general well-being of the rest of humanity, a contribution that developed nations are expected to make a bigger effort. The demand for energy to sustain economic growth has put a lot of pressure on air quality. Air pollution will not easily go away without a shift from labor-and energy-intensive activities to high-technology, low-polluting industries. Vehicular emissions are a growing concern and the race to produce cheap (USD$2500) automobiles will likely exacerbate traffic jams and air pollution in mega cities, especially those in developing nations including China.

Environmental awareness has been improved worldwide, including in developing nations. However, finding a balance between economic development and environmental protection is difficult for developing nations because they are focused on economic growth. The key question is how soon developing nations will tip the balance in favor of the environment, so that they can help to improve the air quality for their citizens and relieve global climate change for themselves.
as well as the rest of the world. The upgrading of the national environmental protection agency to the ministry level is an indication of China’s determination to clean up its environment.

The hosting of the 2008 Olympic Games in Beijing presents a rare opportunity for China to design, plan and build communities using state-of-the-art environmental concepts and technologies. It is hoped that this experience will catalyze and fortify the environmental movement in China and that this is the beginning of the tipping of the balance in the right direction.

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Table 1. The Fourteenth Phase Intensive Control Program and its “5655” strategy

<table>
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<tr>
<th>(1) Five schemes to control pollutants associated with coal combustion</th>
<th>(2) Six vehicular emissions control schemes</th>
<th>(3) Five retrofitting and upgrading of manufacturing facilities schemes</th>
<th>(4) Five schemes to abate re-suspended particulates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate removal, desulfurization and denitrification of coal-fired power plant plumes and decommissioning of hundreds of coal-fired boilers in manufacturing facilities and small power plants</td>
<td>Issuance of new automobile emissions standards</td>
<td>Closing of polluting petrochemical, cement, etc. facilities</td>
<td>Strict control dust emissions from construction sites</td>
</tr>
<tr>
<td>More stringent control regulations for boiler emissions</td>
<td>Decommissioning of high emissions vehicles, buses and taxis</td>
<td>Control of emissions from these facilities</td>
<td>Elimination of barren earth by planting of vegetation or paving</td>
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<tr>
<td>Conversion of domestic coal use to cleaner fuels involving some 50,000 homes</td>
<td>Recovery of fuel vapors at pumping stations and from tankers</td>
<td>Control of industrial emissions of volatile organic compounds</td>
<td>Citywide sanitary and cleaning activities by the residents</td>
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<tr>
<td>Banning of the ad hoc burning of coal in the city/village boundary areas</td>
<td>Restricted use of high emissions vehicles</td>
<td>Abatement of emissions from kitchens</td>
<td>Management of dust from farms and planting fields in the countryside</td>
</tr>
<tr>
<td>Strict control of illegal small boilers and open air burning including barbeques</td>
<td>Banning of large polluting vehicles from the roads</td>
<td>Implementation of more stringent emission regulations</td>
<td>Citizen and community participation in environmental protection projects</td>
</tr>
<tr>
<td></td>
<td>Control of emissions from small stationary diesel generators</td>
<td></td>
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</tr>
</tbody>
</table>
Figure 1. Gross domestic product since the founding of the Peoples Republic of China (Source: National Bureau of Statistics of China, 2005).
Figure 2. Coal and petroleum product usage distribution in China (Source: National Bureau of Statistics of China, 2005).
Figure 3. Concentrations of different components in PM$_{2.5}$ and PM$_{10}$ across China (S+N+A: sulfate + nitrate + ammonium, mass concentrations are used).