Energy Consumption and its Impact on the Environment in Shanghai, China

Weijun Gao¹, Weiding Long², Jianxing Ren³ and Toshio Ojima⁴

¹Associate Professor, Faculty of Environment Engineering, The University of Kitakyushu
Hibikino 1-1 Wakamatsu, Kitakyushu 808-0135 Japan (weijun@env.kitakyu-u.ac.jp)
²Professor, Department of Facilities Engineering and Management, Tongji University
71 Chi Feng Road, Shanghai 200092 P.R.China (weidonglong@online.sh.cn)
³Professor, Department of Power Engineering, Shanghai Institute of Electric Power
No.2103 Pingliang Road, Shanghai 200090 P.R. China (ren66@citiz.net)
⁴Professor, Department of Architecture, School of Science and Engineering, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555 Japan (toshio@ojima.arch.waseda.ac.jp)

Abstract
In this paper, we tried to investigate the situation of the energy consumption increase and its influence on the environment as a result of the economic development of Shanghai. The increase of energy consumption associated with mass production and mass consumption in order to improve the quality of human life is inevitable. But we have to exert the power to change the energy structure and improve the exhaust processing in order to conserve the environment. Observing the characteristics of energy consumption in Shanghai, the air pollution problem is caused mainly by the burning of coal and petroleum. We have found that the density of SOx and TSP in the atmosphere is decreasing year by year because the Shanghai government is trying to adjust the industrial structure and energy consumption. The density of Nox, however, is increasing gradually because of an increase in automobile ownership.

Keywords: Energy consumption; Atmospheric environment; Evaluation; Shanghai

Introduction
Modern society has established a rich material civilization through mass production made possible by consuming a lot of resources and energy. However, due to the huge consumption of energy, many environmental problems have occurred, which exerts a serious influence on the existence of mankind and destroys the regeneration circulation function of nature and exceeds the purification ability of nature. China is one of the countries that receive most attention among the developing countries of the world due to the rapid growth of its economy and urbanization. Shanghai is an economic center of China and its GDP is the highest amongst the cities of China. Therefore, in this paper, we will investigate the energy use and its impact on the environment in Shanghai in order to clarify the structural change of energy use and the relation between energy consumption and air pollution.

Construction and economic development
Shanghai is the biggest city in China with an area of 6340.5 square kilometers and population of 13,110,000 (up to the end of 1999).

Historically Shanghai was one of the most developed cities of the Far East and is now the fastest developing city in China and even in the world. During the past twenty years of the 20th century, the population of Shanghai only increased by 2.1 percent while Gross Domestic Product (GDP) increased by 42 percent.

Fig. 1. Increase of GDP and population of Shanghai in the past twenty years

Contact Author: Weijun Gao, Faculty of Environment Eng., The Univ. of Kitakyushu, Hibikino 1-1 Wakamatsu, Kitakyushu 808-0135 Japan
Tel: +81-93-695-3234 Fax: +81-93-695-3335
e-mail: weijun@env.kitakyu-u.ac.jp
(Received September 10, 2001; accepted December 13, 2001)
Product (GDP) was quadrupled (see figure 1). Up to 1998, per person GDP of Shanghai reached over USD3200 (RMB 2.8 ten thousands, RMB is the currency unit of China, 1USD=8.5RMB).

With rapid development of the economy, the industrial structure of Shanghai has also experienced great adjustment, resulting in a continuous rise in the proportion of tertiary industries (figure 2). In 1985 the proportion of primary industries, secondary industries and tertiary industries GDP was 4.2%, 69.8%, 26%, respectively. In 1999, however, the GDP proportion of these industries became 2.4%, 48%, 49.6%, respectively. Shanghai is aiming to be the center of the national economy, trade and finance.

Energy and economic growth

Energy consumption has been increasing continuously along with the economic growth of Shanghai in recent years (figure 3). However the rate of increase in energy consumption is lower than the rate of economic growth. The energy consumption flexibility value is 0.25-0.5 (The energy consumption flexibility value=energy consumption rate of increase/GDP growth rate).
In 1980-1997, GDP increased about 11 times from USD3.7 billion (RMB315 hundred million to USD39.5 billion (RMB3360 hundred million. Total energy consumption only doubled in this period. Figure 4 shows the relationship between the GDP and energy consumption. Energy consumption of 10,000RMB GDP is to be decreased with year. This means that the efficient use of energy to produce 10,000RMB GDP has been increased in China.

**Energy structure of Shanghai**

Coal and petroleum are the main raw energy source in Shanghai city and the ratio of raw energy consumption is shown in Figures 5 and 6. Coal and petroleum accounted for 70% and 20% of energy consumption in 1997.

Consumption of raw energy is continuing to increase year by year along with development of the economy in Shanghai and coal consumption was 42,160,000 tons in 1997, an increase of 171% in comparison with 1980 and even 54% increased in comparison with 1990.

Petroleum consumption was 10,180,000 tons in 1997, an increase of 68% in comparison with 1980 and 20% in comparison with 1990.

With adjustment of the industry structure, the proportion of business and private dwellings regarding energy consumption will continuously rise (see figure 7). If we consider business and domestic energy consumption as total building energy consumption, we can say that energy consumption by buildings has increased rapidly in Shanghai in recent years. It is estimated that building energy consumption will account for 25% of total energy consumption in 2005, equal to the level of Japan.

The change of energy consumption structure, especially the increase in building energy consumption will affect the environment from
another side.

The main part of building energy consumption is electricity. Figure 8 shows the proportion of building power consumption in total power consumption in recent years. This is bigger than the proportion of building energy consumption.

On-peak power consumption in the summer and the difference between day-on-peak and night-off-peak continuously rises because building electricity demand has increased, especially that consumed by air conditioning system (see figure 9).

**Energy consumption and the environment**

Air pollution in Shanghai is very serious as a result of the burning of coal. Shanghai was one of the ten cities, which had the most serious air pollution in the world in 1995.

The (predicted) discharge of pollutions by coal/oil energy consumption is shown in figure 10 and figure 11 respectively. The discharge of pollution is increasing along with the increase of energy consumption. Figure 12 shows the discharge of pollution due to coal and petroleum use yearly by statistical and predicted data.

Before 1992 the calculated value of SOx was near to the statistical value when compared. The difference becomes greater from 1992. The statistics value was lower than the calculation value. This is because many important measures have been adopted to improve the air pollution problem by energy consumption. The main measurements are as follows:

1) Adjustment of the industrial structure. Some factories that consumed a large amount of energy and released a lot of pollution, have been closed or moved.

2) Improvement in the quality of energy source.

3) The Shanghai Government established some

![Fig.12. yearly change of SOx discharge due to energy use](image)

![Fig.13. Yearly change of SOx, NOx, TSP](image)

![Table 1 Pollution caused by generating 1kWh power of different fuel](image)

| Fuel       | SO2 g/kWh | NO2 g/kWh | TSP g/kWh | CO2 kg/kWh | Pulverized ballast g/kWh |
|------------|-----------|-----------|-----------|------------|--------------------------|
| Coal       | 4.61      | 3.32      | 0.57      | 1.586      | 63.01                    |
| Oil        | 5.49      | 0.68      | 0.30      | 0.860      | 0                        |
| Natural Gas| 0         | 0.40      | 0.06      | 0.605      | 0                        |

![Fig.14. Per person energy consumption and emission of CO2 in different residential areas](image)

![Fig.15. Comparative per person energy consumption of Shanghai with other countries and regions (The data of China was obtained in 1997, Shanghai in 1998 and others in 1995)](image)
strict law regarding environmental conservation in 1992.

4) Adjustment in energy consumption structure. Air pollution has been greatly improved in recent years under the guidelines of the Shanghai government (figure 13). The policy of prohibiting coal boiler being used inside the inner loop has been carried out and the type of air pollution in Shanghai turned from the soot type (first generation) to the compound type (petroleum type plus soot type).

Electric power in Shanghai is generated by burning coal and power plant efficiency is very low in China, which results in serious pollution. So electrical power is not a clean energy source in China (see Table 1).

Per capita energy consumption and emission of CO2 in Shanghai ranked first compared with other cities and provinces in China (see figure 14).

Figure 15 shows that per capita electric consumption in Shanghai in 1998 exceeded the average level of middle-income countries (regions) in the world.

The conclusion can be made that energy consumption in Shanghai has reached the level of middle-developed countries (regions). Although the air quality of Shanghai has been improved in recent years, according to analysis of The 1999' Strategy Report on Sustainable Development in China, which was made by the research group of the China Science Academy, the air pollution index of Shanghai ranked third in 30 cities and provinces of China by counting backwards (the two ahead are Beijing and Tianjin). The integrated field environment level of Shanghai is the worst in China, which is caused by the dense population. The increasing speed of building energy consumption is faster than that of total energy consumption, thus building energy efficiency is one of the key measures to improving air quality in Shanghai. It is urgent to upgrade the level of building energy use and improve indoor air quality of high-rise buildings.

Summary

In this paper, we have tried to investigate the situation regarding the increase of energy consumption and its influence on the environment by the economic development of Shanghai.

The increase of energy consumption associated with mass production and mass consumption is inevitable, in order to improve the quality of human life. But we have to exert the power to change the energy structure and improve the exhaust processing in order to conserve the environment sufficiently. At present, coal and petroleum account for 70% and 20% of energy consumption respectively. Observing the characteristics of energy consumption structure in Shanghai, air pollution problem is caused mainly by the consumption of coal and petroleum.

The density of SOx and TSP in the environment is decreasing year by year because the Shanghai government tries to adjust the industrial structure and energy consumption. The density of Nox, however, is increasing gradually because of an increase in automobile ownership.

Acknowledgment

This research is the result of collaboration with Tongji University, China and is supported by Mitsubishi Foundation.

Reference

1) National Statistics Bureau “China energy statistical yearbook” 1996,1997,1998,
2) Shanghai Statistics Bureau "Shanghai statistical yearbook" 1997,1998
3) Shanghai Plan Committee "Shanghai city energy fiscal year report" 1995,1996
4) Li GuaMo "Measures regarding the sulfur oxide contamination in the Shanghai area" China Environment Science pp1-3 Vol. 16 No. 5 1997
5) Shanghai Environment Bureau "Official bulletin for the Shanghai environmental situation", 1998