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The Characteristics of CO_2 Emission based on the Structure of Energy Consumption - A Case Study in Ningbo, China

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Abstract: In this study the total coal consumption changed in recent years and the data on energy consumptions of different type energy resources were collected and analyzed. The CO_2 emissions from different main industrial sectors and in different districts were calculated based on the data in Ningbo in 2007. According to the calculation results the CO_2 emissions patterns and characteristics were studied. Research results showed that the unprocessed coal was the main energy resource consumed in Ningbo and the total CO_2 emission from Ningbo's main enterprises in 2007 was almost 5 times compared with in 2000. The consumption of the unprocessed coal was mainly consumed at Beilun District among 11 districts in Ningbo and Beilun was the most serious emission region with 44.06% proportion of total CO_2 emitted from the main pollution enterprise. In terms of the relationship between CO_2 emission and industrial sector, the CO_2 emission mainly from Production and Supply of Electric Power and Heat Power, reached 66.90%, followed by Processing of Petroleum, Coking, Processing of Nuclear Fuel. In addition, other factors affected on the CO_2 emission were discussed and the relative suggestions for controlling the CO_2 emission in Ningbo were provided as well.

Key words: Carbon dioxide, coal, emission characteristic, energy, integrated energy consumption

INTRODUCTION

With more and more obvious effect of the greenhouse on the human life, the global warming has become one of the most crucial international issues and the major environmental problem. The human have to face it which challenge all the nations worldwide in 21century. The emissions of greenhouse gases are accepted as the main reason for global warming while CO_2 is one of major components of the greenhouse gases. It has been showed that, nearly 50 years, the global warming mainly caused the warming effect resulted from the utilizations of fossil fuels by release large amount of CO_2 and other greenhouse gases. Since the industrial age, the average temperature of the earth surface has increased 0.7ºC (Boucher *et al*., 2009). Climate warming has produced a series of environmental problems, such as extreme heat waves, melting ice, rising sea levels and more destructive storms etc.

In order to mitigate the problem of global climate warming, the United Nations, the governments, international organizations and academic groups have been stressed the importance of reducing greenhouse gas emissions from the laws and regulations, government documents and technology respectively.

Among the six greenhouse gases covered by the Kyoto Protocol, CO_2, with the longest life cycle in the atmosphere and a significant warming effect, ranked the first one. So that, reducing of CO_2 emission should be considered as the most important task to control global warming (Pan and Liu, 2008). As the first largest carbon emission country, although there is no provision in China's emission reduction targets in the Kyoto Protocol, the CO_2 emission problems has been a hot issue in China concerned by domestic and foreign academia, the environmental community and governments.

In the "Copenhagen Protocol", the 55 countries submitted their commitments and their greenhouse gases emission reduction targets in 2020. Meanwhile, the Chinese government committed to reduce its CO_2 emissions per unit of GDP, or carbon intensity, by 40 to 45% of 2005 levels by 2020. Therefore the CO_2 emission reduction task has become a major challenge for Chinese government to keep sustainable development. In fact, nearly 100 years, the annual average temperature of earth surface in China has been increased significantly, rising about 0.5-0.8ºC, slightly higher than the global average one over the same period (0.6±0.2ºC) (Yang, 2008). Chinese government would take the responsibility and apply mitigating measures to control globe warming together with the other nationals.

In the last decade, there were a number of studies on national or regional scales CO_2 emission analysis and forecast (Xiang *et al*., 2009; Wang and Zhu, 2008; Jin,

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2007; Qian and Yu, 2003; Zhu et al., 2010), in which the studies on the relationship between energy consumptions and CO_2 emissions also were involved in (Choi and Ang, 2001; Schipper *et al*., 1997; Graeber *et al*., 2005; Wind and Wallender, 1997; Soytas *et al*., 2007; Guo *et al*., 2010; Murtishaw *et al*., 2001; Sajjad *et al*., 2010). The relationship between energy consumptions and CO_2 emissions in the specific industry sector has been paid more attentions (Murtishaw *et al*., 2001; Qian and Yu, 2003; Guo *et al*., 2010), but there was not much taking the characteristics of urban economic development into consideration among these kinds of studies.

Ningbo is a key area of the energy construction projects in China and an important base for producing the secondary energy in East China. There are over 10 large-scale cogeneration and coal-fired power plants in the city. The main proportion of coal consumption was for the power and heat productions.

From 1998 to 2008, the coal consumption for the secondary energy productions showed an increasing trend, in which the increase of coal consumption for the electrical power production was higher than for others. In 2008, coal consumption for secondary energy production in Ningbo was 27.9405×10^6 t, and it was 4 times in 1998 (6.7304×10^6 t) (Ningbo Municipal Statistics Bureau, 2009). The meteorological statistics showed that the annual average temperature of earth surface in Ningbo has been increasing with a rate of 0.74ºC per 10 years since 1980. The rate was higher obviously than the growth rate of the global annual average temperature of earth surface It was also reflected an increase of the number of days with extreme higher temperatures; a decrease of the number of days with lower temperatures; urban heat island effect become more and more obvious; and accompanied by increased the number of haze days and decreased the number of snow days. So that, the study on the energy consumptions and CO_2 emissions in Ningbo is useful and helpful for local government to make policy decision on energy saving, CO_2 reduction and air quality improvement.

Accurately estimating the amount of CO_2 emissions is the first step to solve the increase of CO_2 concentration. Based on the estimate the mitigation measures could be proposed. There are a variety of methods to estimate the amount of CO_2 emissions, such as measuring method (Xu *et al*., 2005), material balance algorithm (Zhang and Zhang, 2005), apparent energy consumption estimation method (Wang, 2006), pollutant coefficient method (Wang and Zhu, 2008) and other methods based on all or part of measured data. While other methods are using mathematical models to calculate and predict the amount, such as the ERM-AIM / emission model of China's energy, LOGISTIC model (Qiu *et al*., 2002), MARKAL dynamic linear model (Chen and Wu, 2001), ORNL model (Qian and Yu, 2003; He and Kang, 2008)

Fig. 1: The administrative map of Ningbo

and boiler emission of carbon model (Mei and Han, 2000). It should be noted that for each method, it has its characteristics and limitations. In this study we used the apparent energy consumption estimation method to estimate the energy-produced CO_2 emissions in Ningbo.

MATERIALS AND METHODS

A brief introduction about Ningbo: Ningbo is located in coast of the East China Sea, the south of Yangtze River Delta and Ning-Shao Plain. With the moderate latitude, the weather of Ningbo is belonged to a northern subtropical monsoon climate. It appears mild and humid. The summer and winter monsoon alternate clearly. Ningbo has a long coastline, 1562 km, with deep-water seaport and 531 scattered islands (Ningbo Municipal Statistics Bureau, 2009). Due to the specific geographic location and natural environment, Ningbo has become a key investment city for long time in history. Now, there are six districts, Haishu, Jiangdong, Jiangbei, Zhenhai, Beilun and Yinzhou, five county-level cities under the jurisdiction of Ningbo, Yuyao, Cixi and Fenghua, Xiangshan and Ninghai (Fig.1). The total land area of Ningbo is 9.816 km^2, with the urban area of 2.462 km^2. The population of Ningbo is 5.7102 million with 2.218 million living in the urban area. In recent years, the economic development of Ningbo is very rapidly. In 2007, the total industrial output value of Ningbo reached 236.2×10^9 Yuan (RMB), about 8.5% over the previous year. All of the industrial added value achieved 200.7×10^9 Yuan (RMB), an increase of 4.1% has been archived (Nigbo Municipal Statistics Bureau, 2010)

The data collection: The study was carried out from June 2009 to June 2010 under the supported by the funding to

Table 1: The convert coefficients of standard coal for different energies

Types of energy	Convert coefficients (tce).A
Raw coal (t)	0.7143
Fine-washed coal (t)	0.9000
Other washed coal (t)	0.2850
Shaped-coal (t)	0.6343
Coke (t)	0.9714
Other coking products (t)	1.3000
Coke oven gas ($10^6 m^3$)	614.30
Blast furnace gas ($10^6 m^3$)	128.60
Liquefied natural gas (t)	1.7572
Natural gas ($10^6 m^3$)	1330.0
Crude oil (t)	1.4286
Gasoline (t)	1.4714
Kerosene (t)	1.4714
Diesel (t)	1.4571
Fuel oil (t)	1.4286
Liquefied petroleum gas (t)	1.7143
Refining plant dry gas (t)	1.5714
Others (tce)	1.0000

the Research Project on Air Quality Impacted by Energy Consumption in Ningbo.

The data for this study was mainly from the General Survey of Pollution Source in Ningbo, meanwhile, part of the data was from the "Ningbo Energy" (Ningbo Municipal Economic Commission and Ningbo Municipal Statistics Bureau), "Environmental Quality Report in Ningbo" (Ningbo Environmental Protection Bureau), "Ningbo Statistics Yearbook" (Ningbo Municipal Statistics Bureau) and China Energy Statistics Yearbook (National Bureau of Statistics of China). Based on these data, the statistics and analysis of energy consumption from various sources were worked out in different regions and key industrial sectors.

The calculation of the CO_2: According to the result of the General Survey of Pollution Source, there were 19 different energy resource consumed by main pollution enterprises in Ningbo[1], including raw coal, fine-washed coal, and other washed-coal, shaped-coal, coke, coke oven gas, blast furnace gas, natural gas, liquefied natural gas, liquefied petroleum gas, refining plant dry gas, crude oil, kerosene, gasoline, diesel, fuel oil, other fuels, heating power and electric power. In this study the emission of CO_2 from heating power and electric power consumptions were not calculated since heating power and electric power are secondary energy produced by other energy such as coal and oil.

Since the different energy resource contain different amount of energy, the primary energy consumption data can not be compared simply. The data of the different types of energies usually are converted into standard coal equivalent (tce, ton of standard coal equivalent) or standard oil equivalent (toe, ton of standard oil equivalent). Due to coal is the major energy resources in China for long time, all other type energies are converted into standard coal in both realistic life and theoretical study (Table 1).

According to Tao (2006), the amount of CO_2 emissions (Eco_2) was calculated based on the following formula:

$$Eco_2 = \text{the amount of standard coal (tce)} \times 2.493$$

RESULTS

The total coal consumption changes in Ningbo: From 1999 to 2008, the total coal consumption in Ningbo is summarized in Table 2. It shows that the amount of coal consumptions has been increased within 10-year period except in 2005. Particular in 2007, a significant increase reached. The total coal consumption was 30.4828×10^6 t, while 30.3613×10^6 t, means 99.60% of the total coal consumption, was burned for the industries. It increased 38.63% compared with the previous year. On the contrary, the coal consumptions for resident were kept no obvious change.

Energy consumptions of the main enterprises in Ningbo: The enterprise, which consumes more than 3,000 tce/year, is identified as a main energy consumption enterprise according to Ningbo government. The different types of energies and their consumptions used by main enterprises in Ningbo are listed in Table 3. It shows that, among various energy resources, coal and crude oil are the most important energies. In 2007, the consumptions of these 2 kinds of energies reached 86.37% of total energy consumptions. The raw coal consumption of the main enterprises amounted to 28.11×10^6 t. It was the most abundant energy resource, and accounting for 74.38% of the total energy consumption by the main enterprises. Meanwhile, annual crude oil consumption of main enterprises was 2.27×10^6 t, equivalent to 3.24×10^6 tce. It was accounting for 12.00% of total energy consumption by the main enterprises.

The spatial distribution of coal consumption in Ningbo: Table 4 shows the coal consumptions in 11 regions of Ningbo. The coal consumptions in almost all regions are over 55% of the integrated energy consumption, which add all types of energy consumption after converted them into standard coal, (except in Zhenhai district). In Ninghai and Xiangshan counties, the coal consumptions are even accounted for more than 99% of the integrated energy consumption. From the view of absolute amount of coal consumption, Beilun district is the largest coal consumption (9.80×10^6 t/a) region, Jiangbei district is the second one (8.02×10^6 t/a) and followed by Xiangshan county (6.07×10^6 t/a).

The energy consumptions of major industrial sectors in Ningbo: The top 10 industrial sectors in energy consumption in Ningbo in 2007 have been listed in Table 5. It shows that energy types and consumptions in

Table 2: The total coal consumption changed from 1999 to 2008 in Ningbo

Year	Industrial consumption(10^4 t)	Residential consumption(10^4 t)	Total consumption (10^4 t)	Industrial consumption/ Total consumption (%)
1999	778.43	16.60	795.03	97.91
2000	920.17	22.55	942.72	97.61
2001	1250.29	19.22	1269.51	98.49
2002	1274.30	22.29	1296.59	98.28
2003	1443.72	22.17	1465.89	98.49
2004	1582.60	22.97	1605.57	98.57
2005	1542.72	26.53	1569.25	98.31
2006	2190.13	21.32	2211.45	99.04
2007	3036.13	12.15	3048.28	99.60
2008	3109.14	19.03	3128.17	99.39

Table 3: The different energies consumed by main enterprises in 2007

Types of energy	Amount of consumption	Converted into standard coal equivalent(10^3 tce)	%
Raw coal	28.11 (10^6 t)	20078.88	74.38
Crude oil	2.27 (10^6 t)	3238.12	12.00
Refining plant dry gas	625.99 (10^3 t)	983.68	3.64
Fine-washed coal	869.08 (10^3 t)	782.17	2.90
Fuel oil	450.31 (10^3 t)	643.31	2.38
Coke	629.57 (10^3 t)	611.57	2.27
Natural gas1	1.66 (10^3 m^3)	155.12	0.57
Diesel	86.98 (10^3 t)	126.74	0.47
Blast furnace gas	85.32 (10^3 m^3)	109.72	0.41
Coke oven gas	16.04 (10^3 m^3)	98.52	0.36
Shaped-coal	100.51 (10^3 t)	63.75	0.24
Liquefied petroleum gas	33.75 (10^3 t)	57.85	0.21
Others	20.18 (10^3 t)	20.18	0.07
Gasoline	9.67 (10^3 t)	14.23	0.05
Kerosene	5.74 (10^3 t)	8.45	0.03
Other washed coal	5.55 (10^3 t)	1.58	0.01
Liquefied natural gas	0.77 (10^3 t)	1.36	0.01
Total		26995.23	100.00

Table 4: Coal consumptions used by main enterprises in 11 regions in 2007

Region	Raw coal (10^6 t)	Converted into standard coal equivalent(10^3 tce)I	Integrated energy consumption (10^3 tce)	Converted raw coal/ Integrated energy consumption (%)
Beilun	9.80	7003.7	11895.1	58.88
Jiangbei	8.02	57.3	868.0	6.60
Xiangshan	6.07	4334.7	4352.1	99.60
Ninghai	6.05	4319.0	4345.9	99.38
Zhenhai	2.77	1981.7	3450.1	57.44
Yuyao	1.01	723.2	850.5	85.03
Cixi	0.91	651.8	742.3	87.81
Yinzhou	0.65	463.0	634.5	72.97
Haishu	0.45	320.9	326.8	98.19
Fenghua	0.17	122.7	143.2	85.70
Jiangdong	0.14	100.8	167.9	60.04

these industrial sectors varied widely. Such as in the sector of electricity, heating production and their supply, the major energy was coal, up to 24.76×10^6 t/a. This consumption was 97.94% of the total energy consumption in this sector. Meanwhile, in the sector of Processing of Petroleum , Coking, Processing of Nuclear Fuel the main energy resource was crude oil with 71.76% proportion of total consumption in this sector. In Table 5, it also shows that the sector of Production and Supply of Electric Power and Heat Power consumed the largest amount of integrated energy, up to 18.06×10^6 tce in 2007, followed by the sector of Processing of Petroleum, Coking, Processing of Nuclear Fuel (4.51×10^6 tce), and the third is the sector of Smelting and rolling pressing of Ferrous metals(1.56×10^6 tce).

Analysis of CO_2 emissions characteristics in Ningbo: In order to explain the CO_2 emissions pattern clearly the spatial distribution and the emission feature from the industrial sectors were analyzed and described.

The spatial distribution of CO_2 emissions:

The characteristics of CO_2 emissions from integrated energy consumptions in different regions: The CO_2 emissions calculated from the integrated energy consumptions in all regions of Ningbo are showed in Fig. 2. It shows that CO_2 emissions in different regions have significant differences. The total CO_2 emission from Ningbo's main enterprises in 2007 was up to 67.299×10^6 t, almost 5 times compared

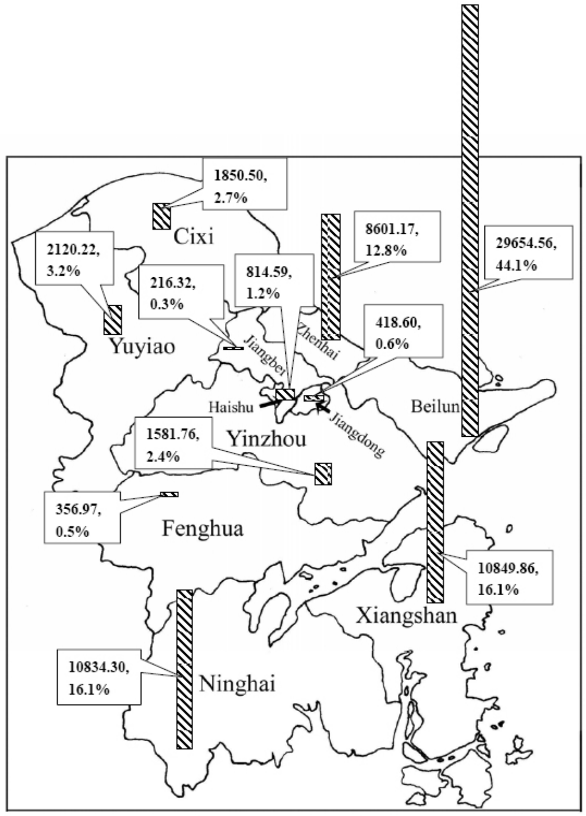

Fig. 2 :The CO_2 emissions from integrated energy consumptions in different regions of Ningbo

Table 5: Energy consumption by major industrial sectors in Ningbo

Industrial sector	Main energy resources	Amount of consumption (10^6 t)	Converted into standard coal equivalent (10^6 tce)	Integrated energy consumption (10^6 tce)	Percentage (%)
Production and supply of electric power and heat power	raw coal	24.76	17.69	18.06	97.95
Processing of petroleum, coking, Processing of nuclear fuel	crude oil	2.27	3.24	4.51	71.84
Smelting and pressing of ferrous metals	fine-washed coal	0.72	0.65	1.56	41.67
Manufacture of paper and paper products	raw coal	1.19	0.85	0.89	95.51
Manufacture of textile	raw coal	0.57	0.41	0.50	82.00
Manufacture of raw chemical materials and chemical products	fuel oil	0.13	0.19	0.25	76.00
Manufacture of general purpose machinery	raw coal	0.21	0.15	0.22	68.18
Manufacture of non-metallic mineral products	raw coal	0.28	0.20	0.30	66.67
Manufacture of chemical fibres	raw coal	0.16	0.11	0.18	61.11
Smelting and pressing of non-ferrous metals	raw coal	0.08	0.06	0.14	42.86

with in 2000 (15.3405×10^6 t). Beilun was the most serious emission region with 44.06% proportion (29.6545×10^6 t/a) of total CO_2 emitted from the main pollution enterprise. Xiangshan and Ninghai placed the second because of almost the same amount of consumption and emission, with 10.85×10^6 and 10.83×10^6 t/a CO_2, accounted for 16.12 and 16.10% of total CO_2 emitted from the main pollution enterprise. The third was Zhenhai with 8.60×10^6 t/a CO_2 emission accounted for 12.78%.

The characteristics of CO_2 emission caused by the main energy types in different regions of Ningbo: Table 6 showsed that the main CO_2 released from coal consumption in the different regions of Ningbo. This part

Table 6: CO_2 emitted from main energy consumption in different regions

Regions	CO_2 emitted from integrated energy consumption(10^6 t)	CO_2 emitted from raw coal consumption (10^6 t)	Proportion (%)	CO_2 emitted from crude oil consumption (t)	Proportion (%)
Xiangshan	10.85	10.81	99.60	15.31	0.00
Ninghai	10.83	10.77	99.38	0.00	0.00
Haishu	0.81	0.80	98.20	0.00	0.00
Cixi	1.85	1.63	87.80	4653.46	0.25
Fenghua	0.36	0.31	85.69	103.28	0.03
Yuyao	2.12	1.80	85.03	0.00	0.00
Yinzhou	1.58	1.15	72.97	252.69	0.02
Jiangbei	0.22	0.14	65.94	0.00	0.00
Jiangdong	0.42	0.25	60.03	0.00	0.00
Beilun	29.65	17.46	58.88	8067584.49	27.21
Zhenhai	8.60	4.94	57.44	35.61	0.00

Table 7: CO_2 emitted from other type of energy consumption in different regions

Regions	Solid fuel consumption (10^3 t)	CO_2 emitted from solid fuel consumption (10^3 t)	Liquid fuel consumption (10^3 t)	CO_2 emitted from liquid fuel consumption (10^3 t)	Gas fuel consumption (10^3 t)	CO_2 emitted from gas fuel consumption (10^3 t)
Beilun	1271.06	3078.77	173.03	368.31	103.90	194.48
Cixi	27.81	67.36	40.42	86.03	0.00	0.00
Fenghua	11.04	26.75	5.91	12.59	0.00	0.00
Haishu	0.00	0.00	4.05	8.62	0.00	0.00
Jiangbei	2.67	6.46	19.37	41.23	0.02	0.035
Jiangdong	0.093	0.23	1.43	3.04	4.88	9.14
Ninghai	6.39	15.48	9.10	19.38	0.00	0.00
Xiangshan	6.06	14.68	5.64	12.01	0.00	0.00
Yinzhou	159.10	385.37	17.15	36.51	0.01	0.015
Yuyao	12.59	30.49	21.78	46.35	6.37	11.92
Zhenhai	107.89	261.34	289.34	615.88	623.83	1167.61

Table 8: Integrated energy consumption and related CO_2 emission from industrial sectors

Industrial sectors	Integrated energy consumptions (10^3 tce)	CO_2 emissions (10^3 t)	Percentage (%)
Production and supply of electric power and heat power	18060.07	45023.75	66.90
Processing of petroleum, coking, processing of nuclear fue	l4509.74	11242.78	16.71
Smelting and pressing of ferrous metals	1563.60	3898.05	5.79
Manufacture of paper and paper products	888.93	2216.10	3.29
Manufacture of textile	496.55	1237.90	1.84
Manufacture of raw chemical materials and chemical products	295.31	736.21	1.09
Manufacture of general purpose machinery	254.42	634.27	0.94
Manufacture of non-metallic mineral products	219.78	547.91	0.81
Manufacture of chemical fibers	180.64	450.34	0.67
Smelting and pressing of non-ferrous metals	135.15	336.93	0.50
Others	390.96	974.66	1.45
Total	26995.15	67298.91	100.00

Table 9: Main energy resource and CO_2 emission from industrial sectors

Industrial sectors	Main energy resource	CO_2 emitted from main energy resource (10^3 t)	Proportion in main enterprises(%)	Proportion in this industrial sector (%)
Production and supply of electric power and heat power	raw coal	44094.85	65.52	97.94
Processing of petroleum, coking, processing of nuclear fuel	crude oil	8067.58	11.99	71.76
Smelting and pressing of ferrous metals	fine-washed coal	1614.87	2.40	41.43
Manufacture of paper and paper products raw	coal	l2113.02	3.14	95.35
Manufacture of textile	raw coal	1022.96	1.52	82.64
Manufacture of raw chemical materials and chemical products	fuel oil	467.15	0.69	63.45
Manufacture of general purpose machinery	raw coal	379.69	0.56	59.86
Manufacture of non-metallic mineral products raw	coal	498.43	0.74	90.97
Manufacture of chemical fibers	raw coal	285.19	0.42	63.33
Smelting and pressing of non-ferrous metals	raw coal	149.96	0.22	44.51

of CO_2 emissions was over 55% of total CO_2 from the integrated energy consumptions, especially in the Xiangshan and Ninghai, the coal-fired CO_2 emissions were 99.60 and 99.38% of total CO_2 emission, respectively. In terms of absolute consumption, Beilun was the region with the largest amount of coal consumption and CO_2 emission (17.46×10^6 t/a) in Ningbo, but the CO_2 emission from coal burning reached 58.88% only while the CO_2 emission from the oil consumption was accounted for 27.21% of total emissions in this region. In comparison, the CO_2 emissions from crude oil consumptions can be ignore.

The characteristics of CO_2 emission caused by other energy types in different regions: In this study, solid fuel included fine-washed coal, coke, shaped-coal and other washed coal. Liquid fuels were fuel oil, diesel, gasoline and kerosene. While refining plant dry gas, natural gas, blast furnace gas, coke oven gas, liquefied petroleum gas and liquefied natural gas belonged to gas fuel. In addition to the two main energies emitted CO_2, the regional CO_2 emissions from other energy sources in Ningbo are listed in Table 7. It showsed that the most CO_2 emissions were from solid fuel consumptions and followed by liquid fuel consumptions. The CO_2 emitted from solid fuel consumption in Beilun was the top one meanwhile those from liquid and gas fuel consumption in Zhenhai was ranked the top.

The characteristics of CO_2 emission from the industrial sectors:

The characteristics of CO_2 emissions from integrated energy consumptions in the industrial sectors: The summarized data of integrated energy consumptions and CO_2 emissions from all industrial sectors showed that the most CO_2 emissions were mainly form the sector of electricity, heating production and their supply. Its proportion of CO_2 emission was 66.90% of total emissions from the main enterprises (Table 8). Followed by from sector of petroleum processing, coking and nuclear fuel processing, the proportion of CO_2 emissions was 16.71% of total emissions from the main enterprises. The proportion of CO_2 emissions (5.79%) from the sector of black metal smelting and rolling processing was the third. These three key sectors contributed 89.40% of total in CO_2 emissions from the main enterprises, and sum proportion of CO_2 emissions from other industrial sectors was 10.60% only.

The characteristics of CO_2 emission from the main energy consumptions in all industrial sectors: Further analysis of energy utilizations in the major industrial sectors showed that the contribution of CO_2 emissions were different in various industrial sectors due to using the different types of energy (Table 9). The coal consumption in the sector of Production and Supply of Electric Power and Heat Power made 44.09×10^6 t/a of CO_2 emissions. It accounted for 61.31% of total CO_2 emissions by the main pollution enterprises, and a proportion of 97.94% of total CO_2 emissions in this sector. The results implied that this sector is in the first place of the CO_2 emissions in Ningbo. Because the main energy consumption was crude oil, the sector of Processing of Petroleum, Coking, Processing of Nuclear Fuel contribution of CO_2 was relatively smaller, although the ranked second place of CO_2 emissions in Ningbo.

DISCUSSION

With the deeper understanding of the global climate change, the reasons found out, related technology development and its applications on the CO_2 emission control, some successes on the control of emissions of CO_2 have been got in developed countries and regions, which are major CO_2 emission countries in the world. According to data analyzing, the CO_2 emissions in the United States, Japan and the former Soviet Union's had showed downward trend over the last decade, but in China, the CO_2 emissions are still increasing (Xiang *et al*., 2009).

The extensive use of fossil fuels in industry is one of the main factors resulting to CO_2 emissions (Zhu *et al*., 2010; Zeng and Pang, 2009). It is more obvious in the developed countries and newly industrialized countries (Soytas *et al*., 2007; Soytas and Sari, 2009). A long-term observation on the relationship between the CO_2 emissions and energy consumption in Korea showed that the impact of the energy intensity on carbon emissions is greater than that of the aggregate carbon factor (Choi and Ang, 2001). The similar work has been done in other developing countries (Rajesh *et al*., 2003; Chebbi and Boujelbene, 2008; Bialecka, 2003).

In China, the studies on the relationship between the industrial energy consumption and CO_2 emissions were less. Some references involved in this area were mainly focus on forecasting or the macro-scale research (Qin *et al*., 2008; Zhu *et al*., 2006; Shuai and Yuan, 2009; Mu *et al*., 2002; Zhen *et al*., 2009).

Due to using the fossil fuel as the main energy, the CO_2 emissions from energy consumption increased with the increase of the energy consumptions in Ningbo. The similar processes had been also appeared in other newly and developing countries such as Korea and India (Choi and Ang, 2001; Rajesh *et al*., 2003). The statistic data from all provinces and autonomous regions in China showed that the ranks of provinces for CO_2 emissions did not changes in recent years; the CO_2 emissions from the coal industry had a significant impact on CO_2 emissions in all province; the reduction amount of the CO_2 emission was larger in the provinces with earlier economic restructuring; some of the less developed provinces and regions with low CO_2 emissions, but emission trends appeared worse and worse, and CO_2 emission transfer cross regions was very obvious (Zeng and Pang, 2009; Wang and Zhu, 2008).

Due to its special location and economy position, Ningbo plays an important role in east China as an energy conversion base, therefore the CO_2 emissions in Ningbo has a very unique phenomenon. Ningbo is not a raw materials base for the energy production in China, all the basic raw materials for energy production in Ningbo comes from other regions and abroad. The energy consumptions of local companies are not too much. But the large proportion of energy-consumptions is for the energy production industries, such as electricity, heat production and supply industry (Table 9). This industrial sector exists for the secondary energy transformation actually by consuming original fossil fuel. The majority of secondary energy consumption is not used by local industries themselves, but CO_2 emitted from the process during the transformation of energy was released in Ningbo. Similar phenomenon presented in other parts of China, like in Shanxi, Shaanxi, Inner Mongolia, Ningxia, Guizhou and Yunnan (National People's Congress of the People's Republic of China, 2001), and as well in Australia (Yu, 1989) and the United States (Hu, 1997). In these places, there are lots of generation plants near coal mines in the energy and raw material bases, the main role of the plants is conversion the primary energy to the secondary one without the long-distance transportation of raw materials. This is the way to save the procurement of coal, transportation, storage and other costs, to reduce the losses in the logistics and to increase the economic benefit. Meanwhile, more social benefits have been obtained, such as lower energy consumption during the electronic transmission, fewer emissions and so on. In processes, the fossil energy conversion industrial sectors supplied a large number of employment opportunities, enhanced the local GDP. For the local social stability, it has played a significant role. But on the other hand, some serious environmental problems have been appeared in these places at the same time.

The Copenhagen Accord had been concerned as the most important document to be complied with for many primary and secondary energy producing regions in China. The control and reduce greenhouse gases emission have become one of the central tasks for the central government and the business leaders. For Ningbo, how to reducing CO_2 emissions significantly without affecting the social development is a key issue. The reduction involved in not only the reducing technology itself, but the urban development planning, industrial construction and layout, and other local laws and regulations as well. Since the actual situation of Ningbo, its industry characteristics and their contribution to local social development, it is not realistic to adjust industrial construction roughly or simply, or even to cut the secondary energy conversion industry. Blindly emphasized to adjust the energy consumption structure is not useful and effective at present situation of energy and raw material features in China and the actual utilization of energy sources in Ningbo. Because the majority of CO_2 emissions in Ningbo is from electricity, heat and other secondary energy production-related industries, and these secondary energy utilizations are non-local, therefore, CO_2 emissions and emission reduction is actually a cross-regional environmental problem. So that, following measures should be carried out when CO_2 emission reduction task is addressed: improving energy efficiency, applying decarbonization technology, eliminating out of date processes and facilities implementing large-scale carbon trading and environmental cost accounting etc.. Only by using all these measures cooperatively, could the CO_2 emission be controlled and finally be reduced in Ningbo.

CONCLUSION

Ningbo plays an important role in east China as an energy conversion base due to its special location and economy position. From 1999 to 2008, the total coal consumption in Ningbo has been increased except in 2005 and the industry consumed more than 97% of total coal. According to the General Survey of Pollution Source in 2007, raw coal was the most important energy type, reached 74.38% of the total energy in Ningbo. In terms of the integrated energy consumed by different industrial sectors and relative CO_2 emission, Production and Supply of Electric Power and Heat Power was the top one, followed by Processing of Petroleum, Coking, Processing of Nuclear Fuel. Meanwhile due to the most Production and Supply of Electric Power and Heat Power enterprises were located in Beilun District, the largest CO_2 emission came from Beilun.

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End Note:

1 Main pollution enterprises means the enterprises are the important stationary sources of air pollutants according to the proportion of their pollution emissions in Ningbo.