NIPPON STEEL TECHNICAL REPORT No. 94 July 2006

UDC 669 . 1 . 012 . 4 (510) : 669 . 162

Prospects of Iron and Steel Production and Progress of Blast Furnace Route in China

Yoshio OKUNO*[1]

Abstract

This paper reports the results relating to the following four subjects: i) current status and future prospects of iron and steel production in China; ii) equipped plant-size and operating condition of blast furnaces that sustain Chinese big steel production; iii) trends of demand and supply of iron ore and coal for blast furnaces; and iv) challenges and problems entailed by production increases. Competition with China in the raw materials and coal market and excessive production capacity of blast furnaces in China negatively impact blast furnaces in Japan.

1. Introduction

With the growth of the Chinese GDP, Chinese steel production has increased dramatically, and surpassed 200 million metric tons per year (Mtpy) in 2002 in terms of crude steel. While the rapid growth of the Chinese steel market has affected the Japanese steel industry positively, it has also made it difficult for the Japanese steel industry to secure sufficient quantities of raw materials. The rapid increase in Chinese steel production inevitably leads to the competition between the steel industries of the two countries not only in the market of finished products but also in that of raw materials. Furthermore, an excessive steel production capacity or a slow-down of the economic growth in China will lead to the export of a great quantity of semi-finished products from the country, and this will significantly influence the neighboring Asian countries. For this reason, it is important to fully understand the present condition and future prospects of the Chinese steel industry. This paper examines the operating conditions of blast furnaces in China and the trends in the supply and demand of raw materials, prospects the steel production of the country in the near future, and points out problems arising from expanded production.

2. Present Steel Production of China and Future Prospects

Supported by the economical growth policy of the country, the steel production of China has increased remarkably since 2000: the production of pig iron and crude steel reached 252 and 269 Mtpy, respectively, in 2004. **Table 1** shows the national production of iron ore, coal, pig iron, crude steel and steel products of the country and the percentage shares of principal provinces. The number of companies operating blast furnaces plant is estimated at approximately 800, and many of them are located in the north and northeast regions, where there are many coal and ore mines. With respect to the production of finished steel products, on the other hand, the coastal regions are responsible for an overwhelmingly large share. This means that the metal (pig iron and steel) and finished products are produced separately in regions away from each other, and integrated steelmakers producing from metal iron to final products at one location and steelmakers specialized in specific products, which are commonly seen in Japan, are difficult to form. As a result, inefficient use of energy and high costs due to the long-distance transportation of semi-finished products are inevitable.

Table 2 shows the crude steel outputs of major Chinese steelmakers that produced 5 Mtpy or more in 2004 and their growth rates from 2001 to 2004. The companies having a capacity of 6 to 7 Mtpy exhibited high growth rates; they are located in medium-developed regions a little away from the coastal regions. In contrast, the four priority steelmakers, namely the Baoshan Group, Anshan, Shougang and Wuhan, and the steelmakers in the frontier regions showed comparatively low growth rates. The expansions of the middle-scale steelmakers in the medium-developed regions are due to aggressive shutdown of small blast furnaces and construction of large ones through acquisitions of small companies. However, in spite of the rapid increase in the crude steel production in these regions, the supply/demand problem of excessive production of semi-finished products and short supply of finished products persists be-

*[1] ex-Fellow

Table 1 Production of raw materials, iron and steel in each province of China

Items (CY)	Iron ore (1990)	Coal (2003)	Pig iron (2001)	Crude steel (2001)	Steel products (2001)
China total (mil. t/y)	179.3	1326.7	155.5	151.6	160.7
Beijing (%)	0	0.6	5.0	5.3	4.5
Inner Mongolia (%)	5.0	9.0	3.1	3.0	2.4
Shanxi (%)	7.1	22.2	13.4	4.0	3.1
Shandong (%)	3.5	11.1	5.1	4.8	5.2
Liaoning (%)	25.3	4.4	10.2	11.0	10.4
Hebei (%)	26.0	5.0	14.0	13.0	11.6
Shanghai (%)	0	0	9.5	12.4	10.4
Jiangsu (%)	1.7	2.1	2.9	5.6	11.7
Henan (%)	1.1	8.9	3.6	3.5	3.1
Sichuan (%)	6.5	2.4	3.9	4.6	4.0

Table 2 Crude steel output and its growth rate of main companies in China (2004 CY)

	Crude steel (10 mil. t/y)	Growth rate (%)*		Crude steel (10 mil. t/y)	Growth rate (%)*
Bao Gr.	2.14	20.7	Hualing	0.71	151.1
Anshan	1.13	28.2	Tinan	0.69	126.7
Wuhan	0.93	40.0	Handan	0.68	115.9
Shougang	0.85	5.6	Hualing Gr.	0.66	207.5
Maanshan	0.80	104.8	Panzhihua	0.55	30.1
Tangshan	0.77	139.4	Benxi	0.54	50.8
Shangang	0.76	413.6	Baotou	0.54	38.2

* Growth rate from 2000 CY to 2004 CY

cause of an insufficiency of rolling facilities.

The production capacity of pig iron in the whole country is said to be excessive by roughly 80 Mtpy, and that of steel by 60 Mtpy as of 2005. Owing to this imbalance, the international steel trade of China changed dramatically from 2003 to exhibit a rapid increase in the export of semi-finished products: the Chinese export of steel in 2005 is expected to surpass import by no less than 12 million metric tons. This means that China has become another steel exporter and a competitor of Japan in the international steel market.

The future trend of the steel consumption of China is very important in forecasting the trends in the global markets of raw materials and steel products. In relation to this, we estimated the steel consumption of China in the near future based on the relation between apparent crude steel consumption and GDP per person-year. **Fig. 1** shows the relations between the steel consumption and GDP of 14 countries; the apparent steel consumption grows roughly in proportion to GDP up to US$ 5000/person-year. The GDP of China surpassed US$ 1000/person-year, and the steel consumption reached 127 kg/person-year in 2003, and the steel consumption has grown following the same curve thereafter. If the GDP of the country in the near future is given, then we can approximate the steel consumption from the graph. A prospect of the GDP of China was reported by an organization of the United Nations[1]. Then, the steel consumption of the country in this GDP was estimated based on a curve of the latest consumption growth (up-date line in Fig. 1). According to the estimation, it will be approximately 330 Mtpy in 2010 and 650 Mtpy in 2030. The IISI also estimated the steel consumptions of the four BRICs countries up to 2050 by a similar method[2]; **Table 3** outlines the results.

According to the IISI estimation, the very rapid growth of steel consumption in China will continue and slow down from 2030s to 2050s, but at that time, India will emerge as another rapidly growing steel consumer country in place of China. As a result, the world steel consumption in 2050 is estimated at 2,900 Mtpy, roughly three times that at present. While the steel consumption of a country is affected by not only the steel production in the country but also the import and export of steel products and scrap, the steel production of China and India will grow, most probably, roughly in proportion to their respective steel consumptions. Currently, the steel consumption of China is growing at a rate higher than those estimated by various research institutes, and this indicates that the short supply of iron ore and coking coal and the environmental problem will aggravate yet more, and the steel production growth of China will come to a turn earlier than so far expected. Since the supply of iron ore and coking coal is one of the most serious future problems of the Japanese steel industry, it is necessary that the ironmaking organizations of the industry concentrate efforts on the diversification of supply sources and the development of new technologies for using a wider variety of raw materials.

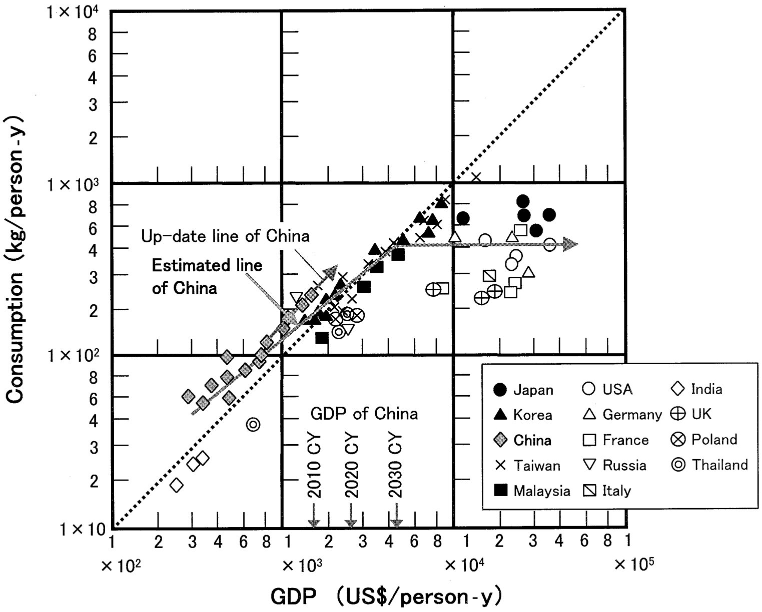

Fig. 1 Relation between GDP and apparent consumption of crude steel

Table 3 Prediction of iron & steel consumption volume of BRICs and World

Unit: 100 mil.t

	2003 CY	2010 CY	2030 CY	2050 CY
China	2.57	3.4	6.1 (4.9 - 7.2)**	6.3
India	0.31	0.5	2.8 (2.0 - 3.7)	5.7
Russia	0.24	0.3	0.5	0.5
Brazil	0.16	0.3	0.8	1.0
BRICs total	3.28	4.5	10.2	13.5
World total*	9.5	11.6	18.9	29.2

* Estimated by Y. Okuno (Assumption of 2%/y growth except for BRICs)
** Numbers in ( ) indicate max. and min. values

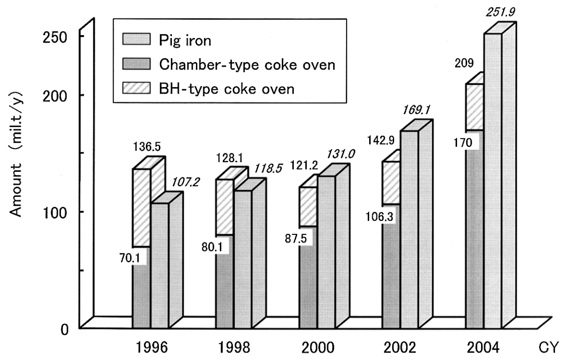

Fig. 2 Production of pig iron and coke

3. Equipment Size and Operation of Blast Furnaces

Fig. 2 shows the growth of pig iron and coke production of China over the last years. The production of pig iron has increased significantly since 2000, reaching 252 Mtpy in 2004. However, this rapid increase in the pig iron production did not result solely from the construction of large blast furnaces. **Fig. 3** compares the pig iron production of China in 2003 with that in 1995 in a breakdown by the size of blast furnaces; note that, because of a change in the definition of statistical data introduced in 2000, the grouping by company size is not the same in the two years compared. In 1995, the blast furnaces of rural companies (average inner volume 44 m^3) were responsible for 18% of the national pig iron production, and in 2003, when the production increased to twice that in 1995, the blast furnaces of miner companies (average inner volume 150 m^3) still accounted for 23% of the national production. This means that not only large blast furnaces but also small ones were actively constructed during the period.

Table 4 shows the number of Chinese blast furnaces 200 m^3 in inner volume or larger in a breakdown by size. In this relation, it has to be noted that statistical reports before 200 said that the number of all the blast furnaces in China was more than 3,000 including those 200 m^3 in inner volume or smaller, but the reports discontinued to cover the small blast furnaces from 2000. As is clear from the table, many blast furnaces 500 m^3 in inner volume or smaller were still constructed, and as of the end of 2003, these small blast furnaces accounted for no less than 30% of the total inner volume of more than 300 blast furnaces in China including those under construction. Then, to check inefficient use of energy resources and further aggravation of environmental conditions, the Chinese Government banned the construction of blast furnaces smaller than a certain limit in 2004. In response to this, large blast furnaces are being constructed in the coastal regions to replace small ones. However, small blast furnaces in the economically under-developed regions are kept in operation because they are indispensable for maintaining employment and tax

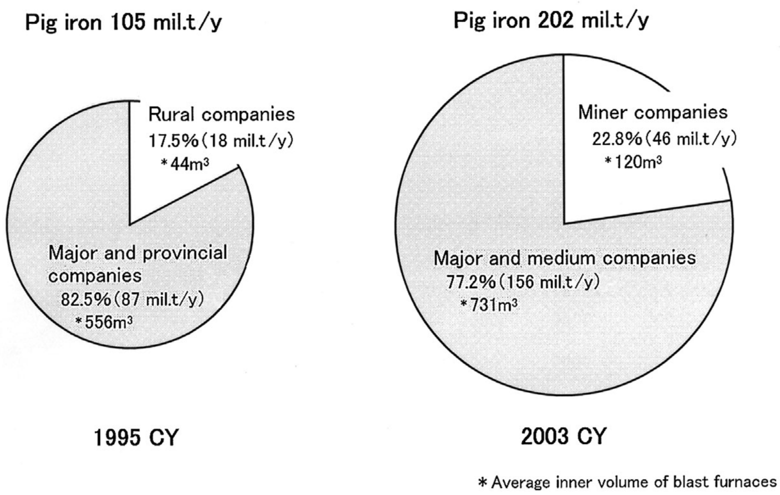

Fig. 3 Steel company size and production of pig iron in China

Table 4 Number of blast furnaces in China

Inner volume (m^3)	200 - 500	500 - 1000	1000 - 2000	> 2000	Total
2001 CY	124	22	29	21	196
2003 CY	164	26	33	24	247
Under building	62	1	10	20	93

Total inner volume of blast furnaces: 153.8×10^3 m^3 / 2001 CY, 1805.8×10^3 m^3 / 2003 CY

income, and thus, the coexistence of large and small blast furnaces still remains widely. A noteworthy fact is that recently there are some plans to construct smelting reduction plants by processes such as Hismelt and COREX to fill the place of small blast furnaces slated to shut down.

Table 5 shows the average figures of the operation data of the blast furnaces of large- and medium-size steelmakers, which account for more than 70% of the pig iron production of the country, in 1995 and thereafter. While the performance of the blast furnaces began to improve from around 2000 thanks to the use of high-quality imported ores and high-strength coke, many of them operate at low blast temperatures, high slag rates and low top pressure, and for this reason, their average coke rate in 2003 was higher than that of Japanese blast furnaces by approximately 50 kg per metric ton of pig iron (kg/t-p). It should be noted, however, that some Chinese steelmakers began to focus attention on the development of technologies for improving the quality of burden materials to increase the amount of pulverized coal injection (PCI). Based on the findings thus obtained, the blast furnaces of Baoshan, for example, have attained an excellent coke rate of 290 kg/t-p and a PCI rate of as high as 200 kg/t-p, approximately, by using sinter having a lower alumina content than that of Japanese sinter and high-strength coke. The performance improvement of Chinese blast furnaces in the future will depend on how rapidly the small blast furnaces, which are operating at coke rates of 700 kg/t-p or higher, are replaced by large ones.

Table 5 Operation of blast furnaces of large and medium-size steelworks

		1995 CY	2001 CY	2003 CY
Productivity	($t\text{-}p/m^3 \cdot d$)	1.80	2.34	2.47
Coke rate	(kg/t-p)	537	444	433
Coal rate	(kg/t-p)	59	124	118
Blast temp.	(℃)	922	1 061	1 082
Slag ratio	(kg/t-p)	480	387	375
Sinter + Pellet	(%)	89.0	91.7	92.4
Fe in burden	(%)	54.6	57.3	58.5
Sinter strength TI	(%)	74.4	71.6	71.8
CaO / SiO_2 of sinter	(-)	1.73	1.75	1.94
Fe in sinter	(%)	52.81	56.07	56.74
Coke strength M40	(%)	80.1	82.1	81.3
Coke ash	(%)	13.77	12.22	12.61
S in coke	(%)	0.63	0.56	0.61

4. Trends in Production and Consumption of Coal and Coke

China is in the third place following U.S.A. and Russia in terms of coal deposits, but it is in the first place in terms of coal production, accounting for roughly 30% of the world total. **Table 6** shows the principal countries' shares of the exploitable deposits and annual production of coal (mainly bituminous and anthracite coals). The coal reserve of China is estimated to sustain about 100 years of mining, which is shorter than 264 years of U.S.A. and 414 years of Australia. The coal production of China has shown a dramatic increase

Table 6 Deposit and mined amount of coal in major countries

	USA	Russia	China	Australia	India	Germany
Deposit (%)	26.1	16.6	12.1	9.6	7.9	7.1
Mined (%)	25.1	4.0	33.2	5.9	8.2	1.2

World total: Deposit amount 945.3 bil.t/y
Mined amount 3.71 bil.t/y (1998 CY)

over the last years, reaching 1,610 Mtpy in 2004. Shanxi Province is responsible for nearly 40% of the national coal production, but the shares of inland regions such as Guizhou Province and Inner Mongolia Autonomous Region are increasing recently. With respect to the size of coalmines, national priority mines account for 47% of the production, provincial mines for 16%, and rural mines for 37%, and thus the rural mines still account for a considerable part of the national coal production. However, the poor performance of these small mines will deteriorate further unless drastic measures are taken to modernize the equipment. The coking coal deposit of China amounts to 23.5 billion metric tons, accounting for 17% of the world total, and its annual production accounts for nearly a half of the national coal production.

While the steel industry is responsible for roughly 15% of the national coal consumption, the mining companies of coking coal are mostly small, and their restructuring into large companies is little encouraged. Furthermore, the development of coking coal mines is said to be more retarded than that of non-coking coal mines. For these reasons, rapid increase in the production of coking coal is little probable. In such a situation, the steelmakers in the coastal regions have been placing emphasis on the import of coking coal, and the import amount hit a record high of 6.76 Mtpy in 2004; the principal supply sources were Australia, Canada and Mongolia. Japan imported 7.61 Mtpy of Chinese coking coal in 2004, but in the latest situation of the world market where coking coal is expected to be in short supply in 2009 and thereafter, how long Japan can continue importing the current quantity of coking coal from China depends on the rate of production increase of the Chinese steel industry. In this relation, the Japanese steel industry will have to further diversify the coal supply sources and develop technologies for use of a wider variety of coal brands.

As seen in Fig. 2, the coke production of China increased rapidly with the increasing production of pig iron, reaching 209 Mtpy in 2004. While this is nearly 50% of the world coke production, as much as 39 Mtpy came from environmentally problematic beehive-type coke ovens, some of them being modified into non-recovery-type ovens. Shanxi Province holds the largest share of the coke production, with a capacity for 80 Mtpy as of 2003, and the capacity of the province is expected to increase to 150 Mtpy when the coke ovens now being constructed are commissioned. In the whole country, however, the pig iron production increased at such a high rate that coke supply became tight since 2000.

In this situation, the price of coke exports (approximately 14 Mtpy in recent years) has risen significantly. In response to the increasing demands, more than 50 coke oven batteries, each having a capacity for 0.4 Mtpy or so, were constructed in 2003, and including these batteries, the coke production capacity of China increased reportedly by 60 Mtpy in 2004. Japan has been importing roughly 3 Mtpy of coke from China, but in the situation where the coke export accounts for 80% of the total amount of the seaborne trade of the country, the present difficulty in keeping the price and quantity of the coke import from China at the current level will persist. Therefore, it is necessary for the Japanese steel industry to secure technology and equipment for continuing to produce high-quality coke without being affected by the change in coal supply sources.

Table 7 shows the production of coke in China and its consumption by the steel industry in 1995 and thereafter. The unit consumption of coke of Chinese steelmakers decreased year by year to record a national average of 568 kg/t-p in 2003 (the Japanese national average was 444 kg/t-p). The unit consumption was improved thanks to the decrease in the coke rate of blast furnaces; the average coke rate of all the Chinese blast furnaces was 500 kg/t-p in 2003. The national averages of the unit consumption and coke rate were higher than those of the Japanese steelmakers by roughly 120 kg/t-p; this is largely due to the fact that small blast furnaces operating at coke rates of 700 kg/t-p or so are still responsible for more than 20% of the pig iron production of China. The future supply and demand of coke in China will depend on the increase in the pig iron production and the replacement of small blast furnaces by large ones.

Table 7 Characteristics of coke consumption in China

		1995 CY	2001 CY	2003 CY
Production of pig iron	(mil. t/y)	105.3	145.4	202.3
Production of coke	(mil. t/y)	135.1	131.3	177.8
Of which: coke from BH ovens	(mil. t/y)	66.5	36.9	39.0
Coke for steel industry	(mil. t/y)	96.2	80.3	115.0
Coke except for steel industry	(mil. t/y)	30.0	29.7	45.0
Export coke	(mil. t/y)	8.9	13.9	14.7
Coke consumption unit for pig iron production	(kg/t-p)	914	552	568
Average coke ratio of all Chinese BFs	(kg/t-p)	640	486	500
Coke ratio of large & medium-size BFs	(kg/t-p)	537	444	433
Coke ratio of residual BFs	(kg/t-p)	1 124	803	728
Coal rate of large & medium-size BFs	(kg/t-p)	59	124	118

5. Trends in Production and Consumption of Iron Ore

The total iron ore deposit of China is estimated at 53.2 billion metric tons, but the exploitable deposit is no more than 9 to 11.5 billion metric tons. As seen with **Table 8**, which shows the principal countries' shares of the deposit and annual production of iron ore, China is the largest iron ore mining country of the world, being responsible for 25% of the world production. The iron ore reserve of China is estimated to sustain 33 to 40 years of mining, which is shorter than 219 years of Brazil and 124 years of Australia. The iron ore production of China increased over the last years and reached 310 Mtpy in 2004. The distribution of Chinese iron ore deposit is uneven: a good part of the deposit is in the northern and northeastern regions[3]. About 50% of the deposit is low-reducibility magnetite and 20% is hematite in fine, and the iron content of either of them is as low as 30% or so. Many blast furnaces in the inland regions use local ores containing impurity elements peculiar to each mine. With respect to the size of mines, national priority mines are responsible for 42% of the production, provincial mines for 15%, and other small mines for 43%; the small mines still account for a considerable part of the national iron ore production.

The price of the iron ores from these mines is high because of the costs for the top soil removal, dressing and transportation to distant steelworks in the coastal regions. For this reason, the coastal steelworks actively import high-quality ores from abroad. Actually, the iron ore import in 2004 amounted to 208 Mtpy; the supply sources were Australia (36%), India (23%) and Brazil (21%). Compared with the iron ore import of Japan, the import from India and Brazil to China is far larger. Over the last three years, the Chinese iron ore import increased from the countries where the Japanese import decreased, and China is now the largest iron ore buyer for all the iron ore exporting countries except for Australia. Since the iron ore import is stressing the cargo handling capacities of Chinese ports to the limits, a significant increase in the production of domestic mines is strongly required to increase the pig iron production to 300 Mtpy and more. In May 2005, the Chinese Government newly introduced a permit system for the iron ore import to check its increase, and at the same time, is promoting development of ore mines at places such as Sichuan Province and Mongolia. The Japanese steel industry presently depends much on the supply of iron ore and coal from Australia, but diversification of supply sources will become increasingly important also for Japan.

6. Prospected Problems

The Chinese steel industry has set out the following as the priority issues: (1) construction of handling and distribution systems for the raw materials and products, (2) establishment of clean production systems (efficient use of raw material and energy resources and environmental protection measures), (3) improvement in production processes by commercial application of advanced technologies and (4) development of next-generation materials. However, the most serious problems in increasing the production will be the supply of raw materials and environmental conservation. A cause of these problems is the low energy efficiency of small- and medium-size steelmakers, especially that of small blast furnaces. The Government is well aware of this, and attempting to regulate the size of new blast furnaces by issuing a series of guidance. However, small- and medium-size steelmakers play important roles as the sources of employment and tax income in the inland regions where the economic growth rate is low, and the Government cannot close such companies without careful consideration.

A problem peculiar to China that cannot be solved by reorganization of steelmakers and introduction of advanced technology is the uneven distribution of energy resources: coal deposits are mainly in the northern, petroleum and natural gas reserves in the northeastern, and hydro energy resources in the southwestern regions, and consequently, energy transportation is costly and optimum combinations of these resources are not realized easily. What is more, coal is responsible for more than 60% of the energy supply of the country, and this makes it difficult to reduce energy consumption. As a result, the CO_2 emission of China is no less than 14% of the world total, an extremely high percentage compared with the share of GDP of 3% in the world economy. The CO_2 emission of the country is expected to increase at an average rate of 3.6% every year to reach 1.82 billion metric tons (reduced into the amount of carbon) in 2020, 1.15 times that of U.S.A. in 2000 (1.58 billion metric tons, same as the above)[4].

According to statistical data covering large- and medium-size steelmakers, the energy consumption of the Chinese steel industry has shown considerable improvement since 2000, but as seen with **Table 9**, the emission of SO_2 and dust is still high[5]. Furthermore, with respect to coke production, the emission of hazardous gas from the coke ovens of Shanxi Province, for instance, accounts for 40% of the total of the province, and that of waste water 30% of the same. Most of the capital investments of the steel industry are allocated to the increase in production capacity, and not to environmental conservation measures. For this reason, further aggravation of environmental conditions is a widespread concern.

Table 9 Environmental practices of Chinese main steel companies

	Bao steel	Main companies
Crude steel (Mt/y)	11.6	158.9
Energy consumption (kg-coal/t-cs*)	656	715
Fresh water (m^3/t-cs)	5.3	15.1
SO_2 (kg/t-cs)	1.79	3.34
Dust (kg/t-cs)	0.50	2.69

* Crude steel

Table 8 Deposit and mined amount of iron ore in major countries

	Soviet-Un.	Brazil	Australia	Canada	China	India
Deposit (%)	34.9	19.9	8.9	6.9	5.3	4.2
Mined (%)	16.3	16.4	13.0	3.5	24.0	6.0

World total: Deposit amount 169 bil.t/y
Mined amount 935 mil.t/y (1992 CY)

7. Closing

This paper has outlined the future prospects of the rapidly expanding Chinese steel industry and the problems related to the blast furnaces of the country that support the increasing steel production. The crude steel production of the country has increased dramatically since 2000, and the apparent steel consumption of China is expected to surpass 300 Mtpy in 2010 and 600 Mtpy in 2030. More than 20% of the rapidly increasing steel production still depends on small-size mines and blast furnaces, and this fact is one of the principal reasons for the aggravation of environmental conditions. The construction of ironmaking equipment is being carried on yet further, and the increased production capacity will depend on overseas sources of raw materials more and more, making the world market tighter. A cause for concern of the Japanese steel industry lies in the runaway increase in the already excessive production capacity of Chinese blast furnaces and the consequent competition against the Chinese steel industry in the raw material market.

References

1) Fu-chen Lo et al.: Chinese Sustainable Development Framework Summary Report. UNU/IAS, Tokyo, 1999-11, p.13
2) IISI Report: Iron and Steel Technology. 2(7), 19(2005)
3) Inazumi T.: a Private Letter
4) Li Zhidong: Proceedings of 13th Conference of Japan Institute of Energy. Tokyo, Jul., 2004, p.20
5) He Jicheng: a Private Letter