

Low Carbon Development of the Iron and Steel Industry

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Abstract: Regard low carbon development strategy of iron and steel industry as the research aim, based on recycling economy, industrial ecology and material flow analysis, in allusion to the question of resource, energy and environment that exist in the development course of iron and steel industry. We propose a series of countermeasures such as taking “reduce, reuse, recycle” as the principle, launching three different scales of recycling of industrial materials extensively, strengthening the material flow analysis for iron and steel enterprise, etc., to implement the low carbon development strategy of iron and steel industry.

Keywords: iron and steel industry; low carbon development; recycling economy; industrial ecology; material flow analysis

1 Introduction

"Low carbon" that was appeared on British energy white paper what is "Our energy future: Establishing low carbon economy" formally first in 2003. It is that a kind of idea and models of low carbon development that reduction carbon emission and slows down the global warming, and become the development trend of the international economic society gradually. Climatic change is the global question that the international community generally pay close attention to, have already become important influence factors of economic and social sustainable development in the future of various countries. International community including developing countries, all for making untiring efforts to climatic change.

At present, the CO₂ emission in China is the second largest emission country only to U.S.A in the world. The CO₂ emission emerging in fossil energy consuming reached 60.18×10⁸ ton^[1] in once energy in China in 2006, it was 4.12 times of 1980, increased by 5.6% every year, especially during in 2002~2006 years, average annual rate of increase is above 10%, be up to 19.3% of peak value in 2004. The proportion accounted for the world has increased by nearly 13% from 7.9% of 1980 year to 20.6% of 2006 year too. The statistics show^[2], among 10 years of 1999~2008, the industrial energy consuming accounts for about 70% of total amount of

energy consuming in China, the high carbon industries which mainly include iron and steel industry, electricity, Non-ferrous Materials, petrochemical industry, building materials, chemical industry, light industry, textile, etc., amount of their energy consuming had accounted for nearly 2/3 of the industrial energy consuming, and the main energy intensities of final product were more 40% than the international advanced industries' in energy consumption^[3]. Especially in recent years, these high carbon industries are presenting accelerating development trend, so this makes China's economy demonstrate "high carbon" characteristic.

At present, China is at fast industrialized stage, under the strong pulling for improving in extensive construction and resident's living standard, the steel production has been developed at full speed in China, and become main motive force of the national economic increase. It can be seen that the iron and steel industry will be also at accelerating development stage in China during the quite a long time of future. So it is a great task that we face how to optimize the structure of iron and steel industry energy, reduce its intensity of carbon, and make its low carbon development of iron and steel industry.

Under this background, the theory such as the recycling economy, industrial ecology and material flow analysis, etc. is as the foundation, launch the research for low carbon development stratagem of iron and steel industry, explore how the iron and steel industry realizes

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the road of low carbon development, improve iron and steel industry energy efficiency, reduce the environmental impact in its manufacturing process, this is an important task that the iron and steel industry develops.

2. Challenge that low carbon development of the iron and steel industry faces

The iron and steel industry is the basic industry, which occupying the important position in national economy. The development of the iron and steel industry has great support function on the development of other fields of national economy. In recent years, the Chinese economic sustained and rapid development, the demand for such basic materials as the steel, etc. is increasing constantly; spur the fast growth of the iron and steel industry in China. Not only the output of steel products increases, its technical level is also promoted comparatively fast, make Chinese iron and steel industry present the tendency of good development.

However, while the iron and steel industry is fast-developing, we should see the development of the Chinese iron and steel industry is facing the severe challenge too. If these problems can't be solved, would become an importance "bottleneck" which will restrict sustainable development of Chinese iron and steel industry. These problems are as follows:

2.1 The contradiction between supply and demand of the energy

China's energy consumption has already become the largest countries of the coal, petroleum and electricity consumption in the world. The energy consumption per ten thousand Yuan GDP of China is 3 times of the average level in the world, is 7.2 times of Japan. The energy intensities of final product is 1.52 tce, and 2.23 times of the developed country 0.68 tce, and they are about 1 time higher than that of the developed country.

The energy consumption of world iron and steel industry accounts for 10% of total energy consumption of the world, the Chinese proportions are slightly large. In the past 30 years, the energy consumption of Chinese iron and steel industry has accounted for 11.8% of the

total amount of national energy consumption^[4], as Fig.1 shows. It can be seen that the energy consumption of iron and steel industry accounts for the proportion of national total energy consumption dropped from 11.76% of 1980 year to 9.17% of 1997 year; Then, the proportion of energy consumption rises by a large margin, by 2006, energy consumption rises to 17.38%.

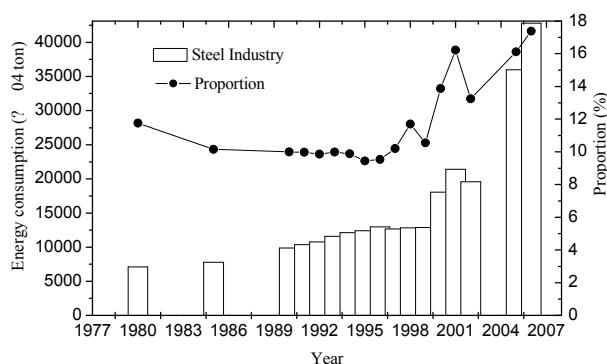


Fig.1 Energy consumption of iron and steel industry takes the proportion of national

The reserves of Chinese energy are in the third of the World. But the proven reserves of only account for 11% of the total amount of world, the crude oil accounts for 3%, the natural gas accounts for 1%, and 10% of less than whole world in total amount of energy. China has 22% of the population in the whole world; the energy per capita is little. Experts predict that the dependence ratios of Chinese petroleum is up to 45%~49% to the outside by 2010^[5]; by 2020, the situation is more severe, and the dependence ratio will rise to 60%~66%.

It is obvious that following the high growth of Chinese economy, the excessive consumption of the energy will make the imbalance between supply and demand of Chinese energy day by day, and the dependence ratio to the outside will rise greatly. So, making Chinese iron and steel industry's low carbon development strategy, saving energy, improving their utilization efficiency, this is that the age gives our duty-bound historical responsibility; and it is the only choice of the iron and steel industry too.

2.2 Increasingly Serious environment Problem

On production and use of the iron and steel, it con-

sumes a large number of resource and energy on one hand; it discharges a large amount of waste gas, waste water and solid offal of industry to the environment on the other hand, and pollutes environment, worsen the space that the mankind rely for existence. Table 1 is the pollutants statistics of the Chinese steel industry of 2005~2006^[6]. It can be seen from table 5 that The volume of Chinese iron and steel industrial waste water, solid waste, sulfur dioxide, soot and dust will increase compared with 2005 in 2006, indicate the emissions of pollutants of the Chinese steel and iron industry presents the trend increased progressively year by year, the environmental situation is severe.

Table 1 the pollutants statistics of
the Chinese steel industry of 2005~2006.

Year	kind	waste water / $\times 10^4$ tons	The Vlume of solid wastes produced / $\times 10^4$ tons	Sulfur dioide / $\times 10^4$ tons	Soot / $\times 10^4$ tons	Dust / $\times 10^4$ tons
2005	Chinese Industry	2430213	134448	2168	949	911
	Iron and steel	169934	23506	142.2	69.3	125.7
	Proportion (%)	6.99	17.48	6.56	7.30	13.80
2006	Chinese Industry	2080440	142053	2041. 8	774. 9	722.2
	Iron and steel	156727	29149	149.4	72.7	113.7
	Proportion (%)	7.53	20.52	7.32	9.38	15.74

Through above-mentioned analysis, we should realize soberly, on one hand the material industries and material researchers make great contribution to national economic development, national defense construction and living standards of the people; but on the other hand, the material industry is the main consumers of resource, energy and the main responsibility of environmental pollution. Facing the threat from overexploitation, deficient and exhausted of resources, and bring the environmental pollution seriously day by day, as the material researchers should reflect these deeply, and actively explore that not only guarantee material performance and quantity demand, but also give the material production technologies of the saving resource, energy and protecting environment, make material sustainable development

strategy. This is duty-bound historical responsibility entrusted to us in era.

3. Countermeasure for iron and steel industry's low carbon development

Based on recycling economy and industrial ecology, exploring the low carbon developing road of iron and steel industry that is suitable for the Chinese actual conditions, taking the path of not only accord with the Chinese reality but also using the experience of various countries for reference; Reducing consumption of resources, energy, decreasing the three kinds of wastes (waste water, waste gas, solid waste) to discharge, improving waste reusing efficiency, it is the task of top priority of implementing low carbon development strategy of Chinese iron and steel industry.

Now introduce the countermeasure of low carbon development of steel and iron industry from these view of "3R" principle, three different scales of recycling of industrial materials and vein industry especially. They are as follows:

3.1 Insisting on "3R" principle

"3R" principle, namely "Reduce, Reuse, Recycle", is a core of the recycling economy, insist on a basic principle that improve the efficiency of resources, energy, protect the ecology environment and promote economic development.

3.1.1 "Reduce" principle

The "reduce" principle is an input end method, aim at reducing the material and energy amount that enters the production process, save resources, energy and reduce emission of pollutants from the headstream, namely doing more with less.

In order to achieve saving resources, energy and reduce wastes, iron and steel enterprises can reduce the consumption of raw materials and energy of unit's production by the aid of technological transformation, adopting advance technology, implementing cleaner production. Such as the development of the iron and steel material of new generation is represented by "reduce production technology", it is a new technology of rolling

steel that is developed both at home and abroad in recent years. With the aid of this technology, it needn't add or add less all kinds of alloy elements to produce the high-performance steel. For example, with the help of optimizing technology, adopting the cooling device of the high density and large flow and low temperature winding measure etc., control the changing course of austenitic, realize the strengthening of fine crystalline and phase transition, improve the toughness and technological features of the steel^[7], well then the strength 200 MPa-grade low carbon steel will reach the 400 MPa-grade performance, save a large amount of steel.

3.1.2 “Reuse” principle

The “Reuse” principle is a process method, means that products continue using after being used or repairing, renovating or making again many times, lengthen the life cycle of the products as much as possible, prevent the products from becoming waste too early.

The iron and steel enterprise has a large amount of equipment that include production and transporting equipment. In the designs of production technology and equipment, we should try one's best to adopt standardized design. In this way we can make resource-sharing of repair piece, reduce stock, can also make production facility upgrade conveniently, needn't change a whole set of facilities.

3.1.3 “Recycle” principle

The “Recycle” principle is an output end method, requires product to turn into the regenerated resources and energy again after finishing its function, thus get back to input end of the processing and begin new round again. It can make the waste turn into resources and energy to the maximum extent, turns waste into wealth. It can both reduce the consumption of natural resources and energy, and reduce the waste also.

The “recycle” of resources and energy not only can delay and even solve the problem of resources and energy exhaustion, but also can slow down the environmental pressure greatly. The data show that the iron ore is replaced to smelt by the scrap steel, then the scrap steel of 1 ton can produce 900 kg steel, save 3 tons ore, can also reduce 86% air pollution emission, reduce 76% wa-

ter pollution, the amount of water consumed is reducible 40%, reduce the mining waste of 97% at the same time, and the energy is only 33% of the ore steel-making.

3.2 Implementing “three different scales of recycling of industrial materials”

The core of recycling economy is the recycling of industrial materials. In industrial system, there are three kinds of recycling flows of materials. They are such as small-scale recycling, middle-scale recycling and large-scale recycling. It is as follows:

3.2.1 Small-scale recycling

Small-scale recycling, is the basic behavior on microcosmic scale of recycling economy. It pursues cleaner production inside iron and steel enterprises according to the idea of industrial ecology^[8], realize the recycling of resources and cascade utilization of energy. For example, it is realized the recycling of wastewater, remaining energy and waste slag etc. in iron and steel enterprises. As you know that the iron and steel enterprises are a traditional high-energy consumption industry. At present, there is a large amount of remaining energy under 100°C ~300°C that can't be totally utilized, a lot of energy from its heat are wasted. So, it is an important way to reclaim the remaining energy (heat) in the process of the iron and steel production, and it is used to heat or power generation.

3.2.2 Middle-scale recycling

Middle-scale recycling, according to the industrial ecology principle and by the aid of the exchange and integrating of the material, energy and information among enterprises, form the relationship of industrial metabolism and symbiosis among enterprises; make the eco-industrial park. And then the enterprises will obtain scale benefit and ecological benefits, increase resources and energy efficiency, and improve the whole economy, society and environment in the park. For instance, an iron and steel eco-industrial park is showed in fig.2^[9]. This park regards iron and steel enterprise as the core, structure such ecological industry chains among the enterprises as steel, building materials plant, machinery plant, chemical industry, electron plant, medicine plant, agri-

culture, food plant, etc., make the ecological industry chains reach more than 70, involve the by product and wastes nearly one hundred kinds. In the eco-industrial park, every enterprise utilizes byproduct and second energy each other, build the more intact closing industry ecosystem among different enterprises, have realized the best configuration and utilization of resources, and make the iron and steel eco-industrial park become a subsystem in the natural ecosystem.

metabolism, as follows: ① offering such energy as the remaining energy and coal gas, etc. to the society; ② treating the wastes in the society, such as the scrap steel, waste plastics, tire and rubbish etc.; ③ deal with the wastewater and sewage of the community by the aid of the water process system of the steel plant; ④ providing the roadbed material for building materials factory and raw materials of the cement.

3.3 Strengthening the material flow analysis for

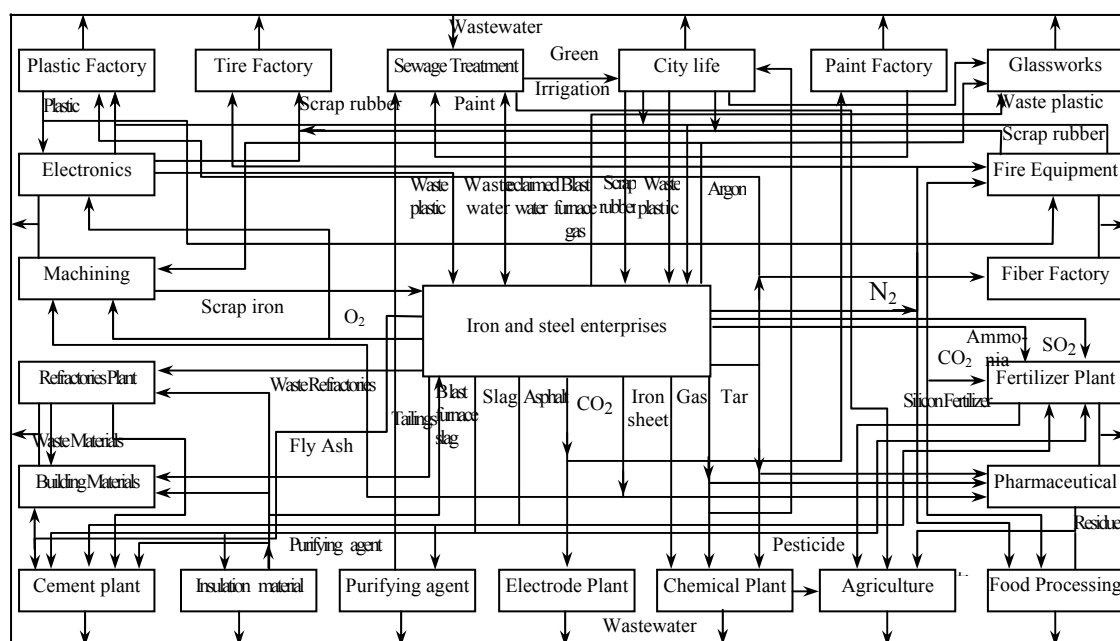


Fig.2 Eco-industrial chain (web) for the iron and steel eco-industrial park

3.2.3 Large-scale recycling

Large-scale recycling is materials recycling between the enterprise and society. In the social aspect, it is important to the recycling of wastewater, reduce and recycling of rubbish, build the recycling type society in the city.

If iron and steel enterprise according to playing an important role in society and economy to decide the think that it develops recycling economy in the future, its produce function can be expanded further, and make it not only have a steel production function, but also have the function of large waste treatment and energy conversion, and offer raw materials, etc.^[10].

The iron and steel enterprise can form the industrial

iron and steel enterprise

The iron and steel industry is a typical process industry, in which iron ore and/or other Fe-containing material are transformed into final product through a series of unit processes. While qualified product of each unit process goes down-stream to its next unit process, unqualified product and other wastes are collected and moved in opposite direction for their retreatment. And, there are usually input and output of a certain amount of Fe-containing material in the midway of the process. Therefore, the scenario of material flow in steel manufacturing process is very complicated. At the same time, the material flow will cause huge influence to energy

intensity. Therefore, the right understanding and analyzing the material flow in steel manufacturing process; will bring far-reaching influence to save energy.

Now, based on the theory^[11] that Prof. Lu zhongwu puts forward, take an iron and steel enterprise as an example, make an influence of material flow in steel manufacturing process on its energy intensity.

Fig.3 is the real material flow diagram for a steel manufacturing process in a steel plant, which consists of five unit processes, e.i mineral processing, sintering, iron making, steelmaking and hot rolling with the ordinal

numbers of 1,2,3,4,5, respectively.

product is calculated, according to Fig.4, as follows:

$$\begin{aligned} E_0 &= 10.3 \times 1.4921 + 69.7 \times 1.7422 + 419.3 \times 1.0599 + 18.2 \\ &\quad \times 1 + 63.5 \times 1 \\ &= 15.4 + 121.4 + 444.4 + 18.2 + 63.5 \\ &= 662.9 \text{ kgce/t} \end{aligned}$$

The results of calculation are shown in Table 2.

Fig.4 is the standard material flow diagram of the manufacturing process, which is worked out on the basis of its real material flow diagram.

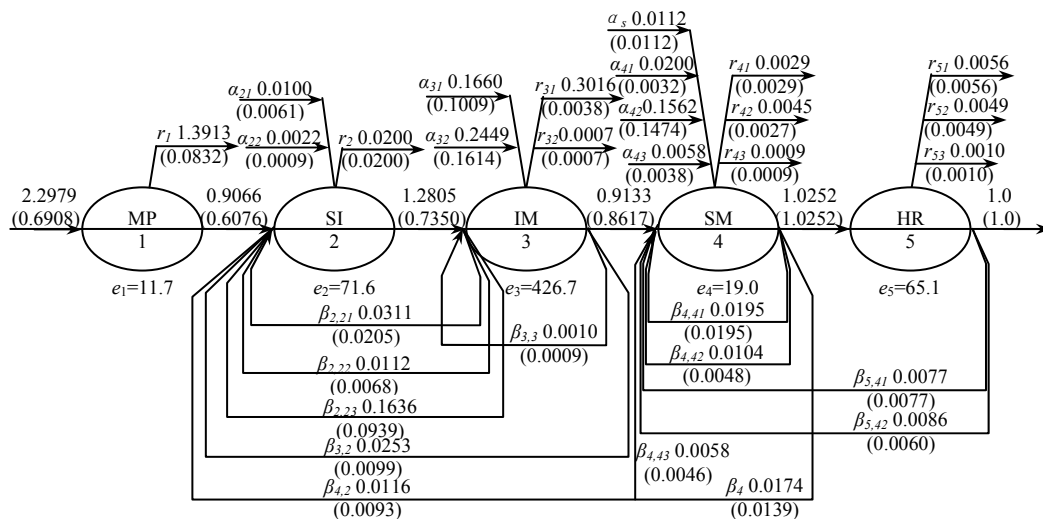


Fig.3 The material flow diagram for a real steel manufacturing process

MP—mineral processing, SI—sintering
IM—ironmaking, SM—steelmaking, HR—hot rolling

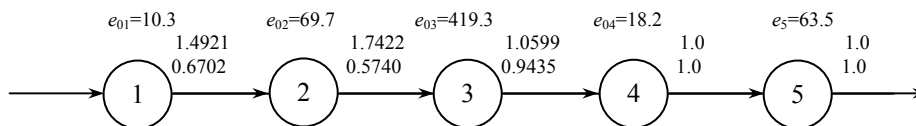


Fig.4 The standard material flow diagram for a real manufacturing process

According to Fig.3, the real energy intensity of final product is calculated as follows:

$$\begin{aligned} E &= 11.7 \times 0.9066 + 71.6 \times 1.2805 + 426.7 \times 0.9133 + 19 \\ &\quad \times 1.0252 + 65.1 \times 1 \\ &= 10.6 + 91.7 + 389.7 + 19.5 + 65.1 \\ &= 576.6 \text{ kgce/t} \end{aligned}$$

Similarly, the standard energy intensity of final

It can be seen that E is 86.3 lower than E_0 , of which 12.8 is due to the differences of unit process energy intensities, and -99.1 is due to the differences of product ratios.

According to the calculation result, it is obvious that the influence of 1 kg increment of steel scrap from rolling for steelmaking is quite different from that of pur-

chased steel scrap for steelmaking. The former increases the energy intensity of final product by 0.0817kgce/t, while the latter decreases it by 0.5812kgce/t. And, the increment of 1kg recycled steel scrap within steelmaking process and from hot rolling mill for steelmaking will cause the increase of energy intensity of final product by 0.0182kgce/t and 0.0817kgce/t, respectively.

Table 2 Comparison between standard (E_0) and real (E) energy intensity of final product

Item	Process (kgce/t final product)					Total
	MP	SI	IM	SM	HR	
E	10.6	91.7	389.7	19.5	65.1	576.6
E_0	15.4	121.4	444.4	18.2	63.5	662.9
$E - E_0$	-4.8	-29.7	-54.7	1.5	1.6	-86.3
Due to process energy intensity	1.2	2.4	6.8	0.8	1.6	12.8
Due to product ratio	-6	-32.1	-61.5	0.5	0	-99.1

4. Conclusion

(1) The iron and steel industry should launch the research of low carbon technology, low carbon process and low carbon energy extensively, etc., to break through bottleneck of resources and energy, reduce and control the environmental pollution, realize the low carbon development of the iron and steel industry.

(2) "Reduce, reuse and recycling" are three important principles, and an important principle that the low carbon development of the iron and steel industry. Adhere to principles, will contribute to iron and steel industry control resources, energy consumption in production source,

course and end of pipe, and implement its low carbon development.

(3) It is an important form in which the low carbon development of iron and steel industry to launch three different scales of recycling of industrial materials extensively, set up the recycling system from material and product design to produce, reclaim and reuse.

(4) The right understanding and analyzing the matter of material flow in steel manufacturing process, will bring far-reaching influence to save energy and decrease iron consumption.

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