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Original Research

Scenario Analysis of Energy Conservation and CO_2 Emissions Reduction Policies in China's Iron and Steel Sector

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Abstract

China's iron and steel sector has met many obstacles, such as high energy consumption and huge CO_2 emissions. In order to deal with these problems, the Chinese government has launched a series of corresponding policies. With the assistance of Long-Range Energy Alternatives Planning System (LEAP) software, this paper established the LEAP policy model to explore performances of industry policies formulated by the government. The model consists of a baseline scenario and three policy scenarios based on different policies. Three policy scenarios in the LEAP policy model are based on policies of phasing out backward production capacity, promotion energy saving technologies, and establishment of a carbon emissions trading market. Results indicate that there is great potential for the CO_2 emissions mitigation in the iron and steel sector. The effects of four scenarios are ranked as follows: emissions trade scenario (ET) > cut excessive capacity scenario (CEC) > technology improvement scenario (TI) > business-as-usual scenario (BAU). From the point of view of the iron and steel industry, this research tries to cast light on the future performances of industrial policies, and the results reveal that CO_2 emissions would be abated significantly if those policies were successfully implemented.

Keywords: China's iron and steel sector, industrial policies, CO_2 emissions reduction

Introduction

Accompanying the rapid development of China's economy is the problem of greenhouse gas emissions from industrial production and consumption, which has caused wide concern of domestic and foreign scholars as well as the Chinese government. In 2013 China's CO_2 emissions from fossil fuel combustion were 9.023 billion tons, which accounted for 28.03% of total global emissions [1]. China's economic growth is likely to continue in the foreseeable future and, therefore, an increase of CO_2 emissions is inevitable. Meanwhile, on the issue of global climate change, China is facing tremendous negotiation pressure from developed countries [2].

Therefore, China shall give equally important position to developing the economy and controlling CO_2 emissions. Various countries have reached a consensus on climate change and its worsening impacts, as well as the related issue of air pollution from burning fossil fuels. The "U.S.-China Joint Statement on Climate Change" issued in November 2014 shows the targets to peak CO_2 emissions

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as soon as possible before 2030. Once this proposal is achieved, China would make a great contribution to the abatement of global CO_2 emissions. In order to achieve this goal, all energy-intensive sectors in China should make appropriate adjustments. Global iron and steel sector CO_2 emissions accounted for 5~6% of total global emissions, while the direct CO_2 emissions from China's iron and steel industry account for about 15% of the total in China [3]. Therefore, the development of low-carbon iron and steel industry will play a significant role in peaking China's overall CO_2 emissions in 2030.

Overview of China's Iron and Steel Sector

China's crude steel production increased rapidly in recent years. From 2011 to 2013, the number of China's newly built blast furnaces were 63, 34, and 31, respectively, which created a new production capacity of more than 138 million tons. In 2014, the production of China's crude steel was 822.7 million tons, which accounted for 50.26% of global total steel output (China Iron and Steel Industry Association, 2015). Fig. 1 shows the production situations of the world's major steel-producing countries in 2014. Although China has a much higher crude steel production than any other country, it cannot be denied that China has a much lower proportion of electric arc furnace (EAF) steel production compared with other countries.

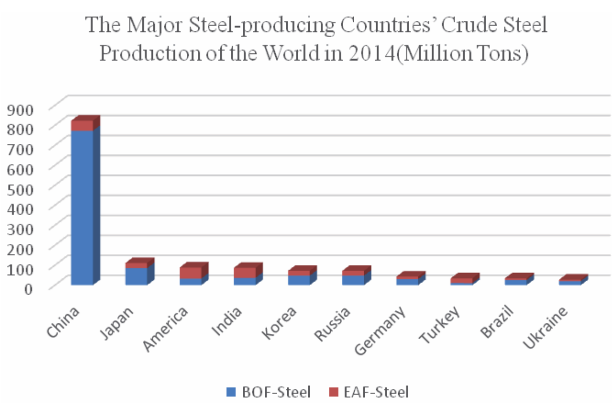

Fig. 1. Crude steel production of the world's major steel-producing countries in 2014.
Notes: Sourced from China Iron and steel Yearbook 2015.

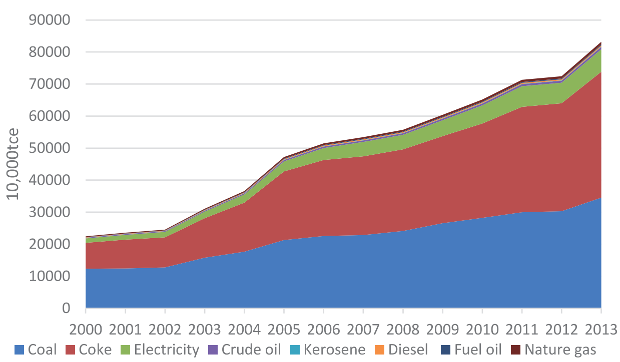

Fig. 2. Energy resources used in China's iron and steel industry.
Notes: sourced from China Statistical Yearbook, 2001-15.

There are eight types of energy resources used in China's iron and steel industry, including coal, coke, electricity, and oil, and the corresponding proportions of these energy consumptions are shown in Fig. 2. With a stable trend from 2000 to 2013, coal and coke are the main energy sources, accounting for about 88% of total energy consumption on average. The next is electricity, which accounts for about 9% of total energy consumption. Nature gas and other oil-related energy consumption provide only a small slice, accounting for less than 3%. Coal-related energy has played a dominant role in China's iron and steel sector, and also produces the most CO_2 emissions.

Along with China's economic transformation, China has been in a "new normal" economy development time since 2013 [5-6]. In 2015 the effective capacity of crude steel in China is more than 1,250 million tons, but the real output is only 804 million tons. The current situation shows that industrial capacity utilization in China is 64%, and that industry is confronted by huge overcapacity.

Overview of China's Iron and Steel Industrial Policies

With the development of China's iron and steel industry, structural problems, including a huge amount of CO_2 emissions, are becoming more and more pronounced. In order to deal with those problems and promote low CO_2 emissions development in the iron and steel industry, the Chinese government has brought forward a series of policies.

On 4 February 2016 the State Council issued "Views on Resolving Overcapacity of Iron and steel Industry and Poverty Alleviation." The document pointed out that the iron and steel industry should trim its crude steel production capacity by 100-150 million tons during the 13th Five-Year Plan (2016-20). At the same time, the Chinese government has introduced other measures to support the process, like closing outdated plants, eradicating "zombie" companies, and suspending the issue of licenses to steel projects.

To speed up the application of advanced energy-saving and emission reduction technologies, the government guides iron and steel enterprises to use advanced technology, new equipment, and new process. This will promote the economical and intensive use of energy resources, relieve the burden on resource and the environment, and reduce greenhouse gas emissions such as CO_2. The "National Key Energy Conservation and Low Carbon Technology Promotion List (2015)," aimed at increasing the application of energy-efficient technologies, has been organized by the National Development and Reform Commission (NDRC). The list includes high-temperature and pressure coke dry quenching (CDQ) – just one of 26 technologies that would be applied to the iron and steel industry. Constructing scrap recycling, processing and distribution system, and developing scrap as a raw material for the electric arc furnace (EAF) process in iron and steel industry are also encouraged by the Chinese government.

In terms of CO_2 emissions control, the NDRC issued the "Notice on the implementation of the national carbon emissions trading market to start" in January 2016, which is aimed at pushing forward development of the carbon emissions trading market, making sure that a domestic emissions market would be started and a corresponding system would be implemented by 2017 [7]. Under the scheme, iron and steel enterprises would have to pay for their over emissions. If one produces more than its share of emissions, the company should ask a company with fewer carbon emissions for help, and buy their unused quotas. The existence of an emissions trading market will help with controlling the total quantity of carbon emissions from the iron and steel industry through initial quotas, and the government can also realize the aim of quantity control of carbon emissions by regulating quotas.

Focusing on the perspective of industrial policies formulated by the Chinese government, this paper builds the LEAP policy model to simulate and analyze the performances of different policies in energy conservation and CO_2 emissions reduction, with the help of LEAP software. This paper attempts to gain a more comprehensive understanding of future direction in CO_2 emissions reduction through a modeling study on the policy effects of China's iron and steel sector.

Material and Methods

LEAP System

This paper applied an extraordinary accounting and scenario-based energy modeling platform, LEAP, which is one of the greatest achievements from the Stockholm Environment Institute. Based on the idea of long-range scenario analysis, LEAP software is expert in energy system analysis [8]. Scenarios could show us about the evolvement of an energy system as time goes by, and which always remains consistent. And scenario simulation calculates and analyzes how energies are produced, converted, and consumed, as well as the influences on the environment within such a process of an industry during its whole life cycle. Thanks to LEAP, analysts could rebuild and assess some new scenarios in the process of making comparisons among energy consumption, efficiency, and effects on the environment [9]. Government could also evaluate the impacts brought about by a specific policy with the assistance of LEAP.

Moreover, LEAP's lucid and versatile data organization is well fitted to an iterative research strategy: the user can start from making the initial analysis easily, and then the user can put some complex factors into some parts that have accessible data or consist of details to provide valuable information directly for analysis [10].

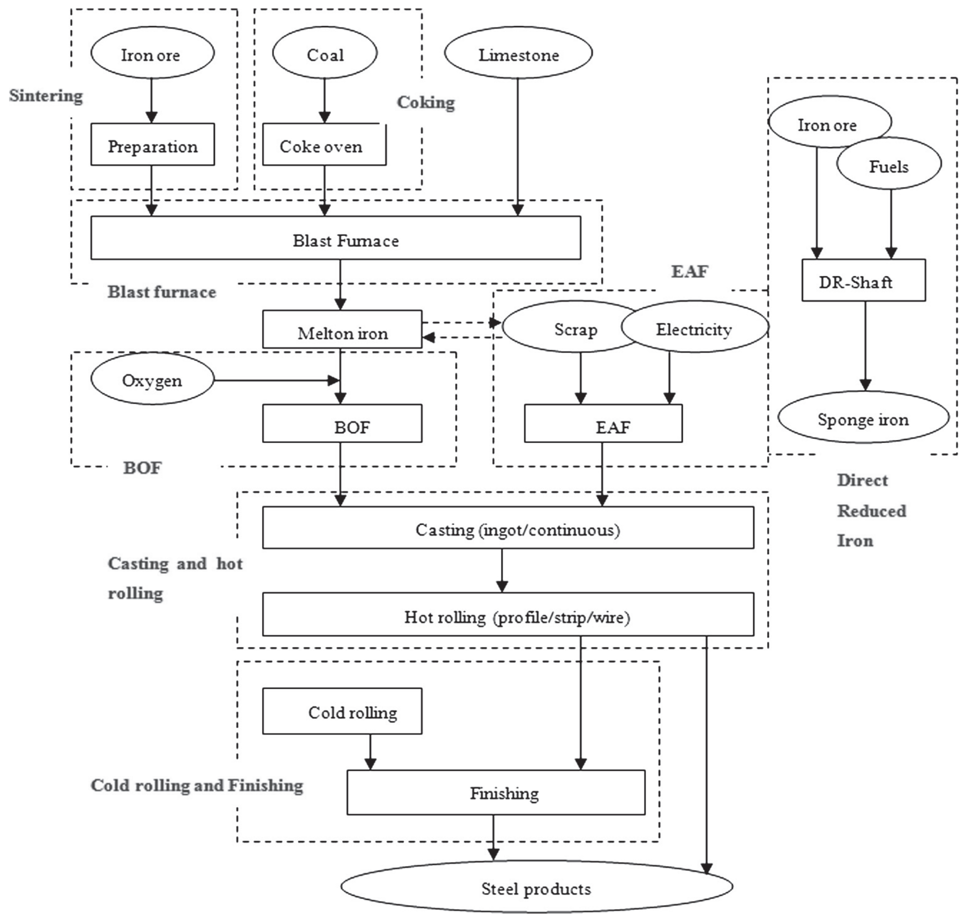

Fig. 3. Main production processes in Chinese iron and steel industry.

With such advantages, LEAP plays quite an important role in accounting for energy demand or supply models. A number of researchers have promoted LEAP due to its efficiency in input and accessing a data set [11-14].

LEAP scenarios are constructed by sobering statistics about different types of energy consumption in the manufacturing process, yearly output, and the specific fuel distribution method in one sector according to alternative predictions about economic development, output capacity, and technology improvement. The same as energy flow in the process of industrial production in reality, LEAP has a bottom-up data structure, and the order of modules reflects that the flow and consumption of energy are successively from the first process of production to the last. Fig. 3 [15] exhibits a simplified manufacturing line scheme that also shows the micro-data structure of the LEAP policy model built in virtue of LEAP software for the Chinese iron and steel industry.

An environmental pollutants emission factor technology-environment database (TED) is also provided in the LEAP platform, and it is possible to calculate emissions including CO_2, SO_2, and NO_x produced during the process of fuel consumption through this database [8]. The analysis procedure followed by the LEAP platform is illustrated in Fig. 4 [10, 16], and can be summarized in the following five steps [8, 17]:

1. Sector production: The production volume of the iron and steel industry is decided by the whole production chain.

$$P_i = \sum P_{j,i} \tag{1}$$

P_i = Production of process "i"
$P_{j,i}$ = Production of process "i" by equipment "j"

2. Energy consumption:

$$\mathrm{E} = \sum_i \sum_j \sum_n ue_{n,j,i} \times P_{j,i} \tag{2}$$

E = Total energy demand of the iron and steel sector
$ue_{n,j,i}$ = unit production output energy demand of fuel type "n" utilized in process "i" by equipment "j"

3. CO_2 emissions: LEAP platform has a performance screen that can be utilized to calculate CO_2 emissions:

$$\mathrm{CE} = \sum_i \sum_j \sum_n cef_{n,j,i} \times ue_{n,j,i} \times p_{j,i} \tag{3}$$

CE = total CO_2 emissions of iron and steel industry
$cef_{n,j,i}$ = CO_2 emissions factor of fuel type "n" consumed by equipment "j" in production process "i"

4. Cost:

$$\mathrm{C} = \sum_i \sum_j \{[ufc_{j,i} + \sum_n ue_{n,j,i} \times uep_n + \sum_k um_{k,j,i} \times ump_k] \times p_{,j,i} \tag{4}$$

C = total cost of the iron and steel sector
$ufc_{j,i}$ = unit fixed cost for per production by equipment "j" in production process "i"
uep_n = unit price of fuel type "n"
$um_{k,j,i}$ = unit demand of raw material "k" utilized through equipment "j" in production process "i"
ump_k = unit price of raw material "k"

5. Energy conservation and CO_2 emissions abatement potentials:

$$\mathrm{ESP} = (\mathrm{E}_0 - \mathrm{E}_a)/\mathrm{E}_0 \tag{5}$$

$$\mathrm{EMP} = (\mathrm{CE}_0 - \mathrm{CE}_a)/\mathrm{CE}_0 \tag{6}$$

ESP = Energy saving potential
E_0 = Total energy consumption of baseline scenario
E_a = Total energy consumption of policy scenario "a"
EMP = CO_2 emissions abatement potential
CE_0 = Total CO_2 emissions in baseline scenario
CE_a = Total CO_2 emissions in policy scenario "a"

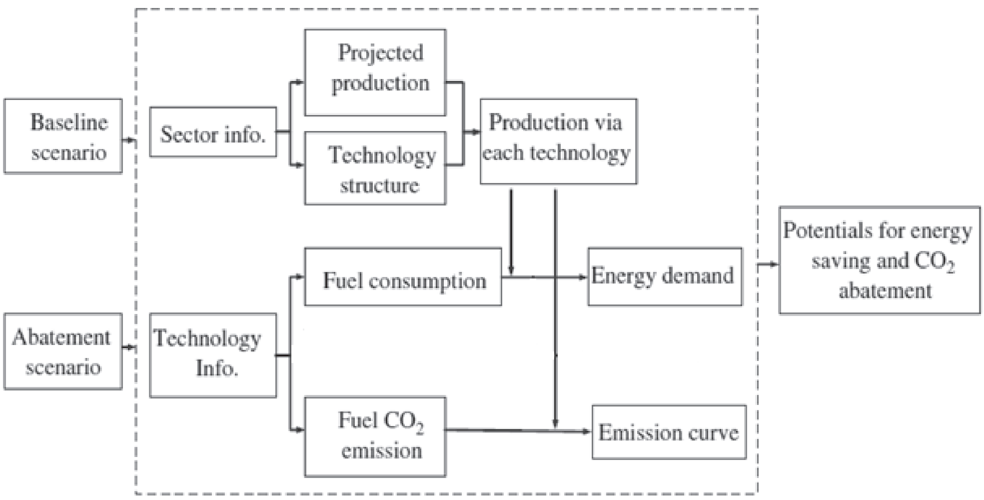

Fig. 4. Structure and analysis process of LEAP system.

Table 1. Basic macroeconomic assumptions in the LEAP policy model.

Indexes	2015	2020	2030	2040
Growth rate of GDP (%/year)	6.9	6.1	5.3	4.5
Urbanization rate (%)	56.1	60.0	67.0	70.0
Population (million)	13.8	14.5	14.3	13.9
Share of primary industry (%)	7.3	5.5	3.6	2.6
Share of secondary industry (%)	42.8	41.5	38.8	36.3
Share of tertiary industry (%)	49.9	53.0	57.6	61.1

Scenario Definitions and Main Assumptions

The aim of this research is to evaluate the future performances of industry policies in China's iron and steel sector. With this purpose, a scenario analysis model named the LEAP policy model has been constructed with the help of LEAP software. The LEAP policy model consists of a baseline scenario plus three policy scenarios.

The four scenarios generated in LEAP policy are:

I. BAU (business-as-usual scenario).
II. CEC (cut excessive industrial capacity scenario).
III. TI (technology improvement scenario).
IV. ET (emissions trade scenario).

BAU is based totally on past trends, which is according to the hypothesis that the past tendency will be lasting and no extra policies will be adopted in the near future, which means that 42.7% of production is produced by small- and medium-sized equipment and the technological upgrading speed is slow [4]. Overall, the BAU scenario will take no account of new industrial policies or other emissions reduction measures. The speed of industrial restructuring and technology upgrading in China's iron and steel sector is slow and the government does not carry out any other new policies to weed out undeveloped production capacity. All in all, the BAU scenario will emphasize the future situation of China's iron and steel sector without additional measures.

The CEC scenario is based on China's 13th FYP (five-year plan) [18] and "Views on resolving overcapacity of iron and steel industry and poverty alleviation" [19]. The CEC scenario assumes that the Chinese government will use administrative means to eliminate 100-150 million undeveloped iron and steel production capacity during the 13th FYP (2016-20). After years of rapid economic growth, China has stepped into the late stage of industrialization. China's economy is facing a transformation from high-speed growth to slightly slower growth. Economic structure in China has changed: tertiary industry's proportion exceeds the secondary industry, and has become the new impetus for China's economic growth. These transformations in the economic growth pattern make the demand strength a sustained downward trend. As a consequence, CEC also assumes that the Chinese government will make a long-term plan on the iron and steel sector in the context of economic transition during the whole projected time interval. The main aim of the CEC scenario is to highlight how China's iron and steel sector will perform under production capacity control policies.

About the TI (technology improvement) scenario, this paper assumes that the iron and steel industry will realize technological upgrading on the basis of the "National Key Energy Conservation and Low Carbon Promotion List (2015)" [20]. This indicates that the Chinese government will promote compulsory energy conservation and emissions abatement technologies in the iron and steel sector. There are 24 technologies on the promotion list, including dry TRT operating in blast furnace at a high rate for long period, and dry quenching at high temperature

Table 2. Some assumptions and parameter settings in each scenario.

Scenarios	Assumptions and parameter settings
BAU scenario	Iron and steel production is extrapolated by the current development trend. Structural adjustment and technical upgrading of the steel industry is slow. The proportion of short-process EAF steelmaking would increase from 6.1% in 2014 to 10% in 2040.
CEC scenario	Crude steel production capacity in China will be slashed by 150 million tons from 2016 to 2020. The proportion of short-process EAF steelmaking would increase from 6.1% in 2014 to 15.7% in 2040.
TI scenario	Iron and steel production is extrapolated by the current development trend. According to the "National Key Energy Conservation and Low-Carbon Promotion List (2015)," the technical promotion situation in 2016-20 is illustrated in Table 3, and 2020-40 is listed in Appendix A. The proportion of short-process EAF steelmaking would increase from 6.1% in 2014 to 15.7% in 2040.
ET scenario	Crude steel production capacity in China will be slashed by 150 million tons from 2016 to 2020. The technical promotion situation in 2016-40 is illustrated in Appendix A. The proportion of short-process EAF steelmaking would increase from 6.1% in 2014 to 25.6% in 2040.

Notes: Sourced from China iron and steel yearbook 2015 [4], China's 13th Five-Year Plan [18], National Key Energy Conservation and Low-Carbon Technology Promotion List (2015) [20], and Views to resolve the overcapacity in the iron and steel industry [19].

Table 3. The improvement proportion of each technology in TI scenario from 2016 to 2020 [20].

Option	Proportion of current promotion (%)	Promotion potential (%)	Energy saving capability (ton/year)	CO_2 emissions abatement capability (ton/year)
1. Sintering				
1.1Generating of sinter waste heat	20	40	150,000	410,000
1.2liquid seal technology	3	10	100,000	260,000
1.3sintering residual heat recovery	3	20	400,000	2,930,000
1.4Waste heat cyclic utilization	<1	30	420,000	920,000
2. Coke making				
2.1High temperature and high pressure CDQ	13	20	510,000	1,250,000
2.2 Winnowing and coal moisture control	5	50	2,000,000	5,280,000
2.3 High conductivity silica brick	3	15	960,000	2,530,000
3. Iron making-blast furnace				
3.1 TRT(dry type)	50	70	650,000	1,720,000
3.2 CCPP	20	40	120,000	330,000
3.3 Dehumidifying blast technology of BF	5	10	750,000	1,830,000
3.4 BPRT	30	50	900,000	2,880,000
3.5 Flushing water waste heat recovery	1	40	1,430,000	3,780,000
3.6 Recuperator on the hot blast stove	10	30	1,100,000	2,900,000
4. Steelmaking-BOF				
4.1 Dry cleaning and recovery technique	20	60	250,000	660,000
4.2 Heat recovery of BOF gas	5	20	300,000	790,000
5. Steelmaking-EAF				
5.1 Dynamic reactive power compensation	20	30	1,500,000	3,960,000
5.2 Waste heat power generation	40	90	440,000	1,160,000
5.3 Cold ramming paste	10	40	800,000	2,100,000
5.4 Direct current arc furnaces	5	20	540,000	1,430,000
6. Hot rolling and casting				
6.1 Reinforced blackbody radiation	15	40	2,200,000	5,810,000
6.2 Hot rolling Hot charging	10	40	110,000	290,000
6.3 Regenerative reheating furnace	57	80	220,000	590,000
6.4 Waste heat recovery	40	90	440,000	1,160,000
7. Cold rolling and finishing				
7.1 High-voltage variable frequency speed	15	50	3,000,000	7,920,000
8. General technologies				
8.1 Energy monitoring and management	40	60	2,700,000	7,130,000
8.2 Refrigerating water circulation system	<7	20	2,070,000	5,460,000

Notes: Sourced from National Key Energy Conservation and Low Carbon Technology Promotion List (2015) [20]

and pressure. Detailed information about specific technologies' emissions reduction potential and promotion proportion from 2016 to 2020 can be seen in Table 3. The purpose of the TI scenario is to explore how China's iron and steel sector will operate with the implementation of those technologies' improvement policies.

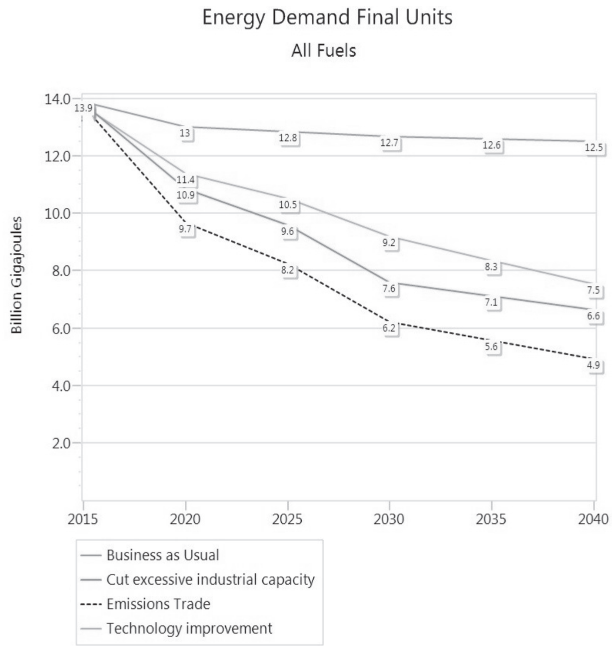

Fig. 5. Energy consumption of different scenarios from 2015 to 2040.

The last scenario in LEAP policy model is the ET (emissions trade) scenario, which is based on policies for addressing climate change. ET assumes that China will launch a national CO_2 emissions trading market (ETM) [7], which will cover the iron and steel sector. Since the government has not announced detailed implementation rules of China's ETM, to simplify analysis this paper assumes that China's ETM is modeled on Europe's. The ETM operates on cap-and-trade principles[21]. Cap is the total amount of greenhouse gas that can be emitted by an iron and steel factory specifically in a predetermined time interval. If the signatory iron and steel companies run out the cap, they must to purchase the emissions allowance from others. They can also auction their spare allowances through the market to make profits [22]. Under the ETM, undeveloped enterprises will decrease their output because of their low benefits and the deficiencies of carbon quota. In the context of the constant demand of the steel market, those who own advanced equipment will have higher production. This means more iron and steel products will be manufactured by high-tech equipment.

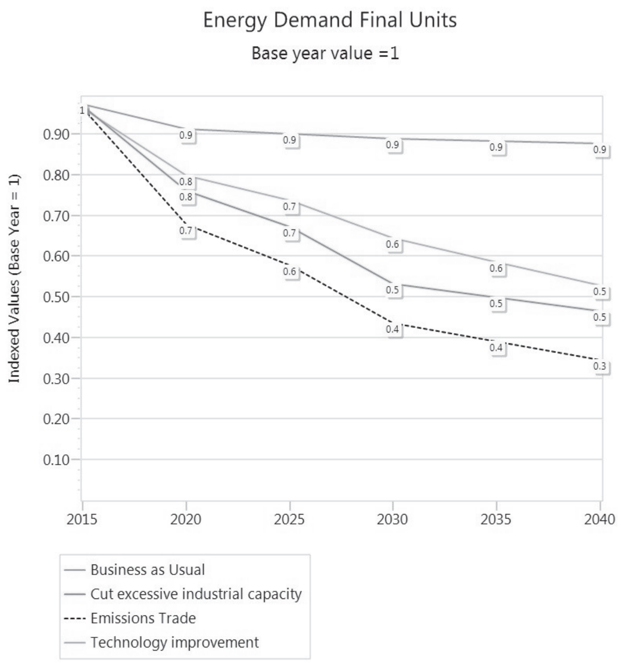

Fig. 6. Energy demand of each scenario compared with the base year value (base year = 2015).

Main Assumptions in the LEAP Policy Model

There are some macro-economic variable assumptions in the LEAP policy model. All assumptions on GDP growth rate, urbanization rate, population, and industry shares are in accordance with the Chinese government's 13th FYP [18], official statistics [23], and published literature [5, 24-26]. The time-interval for all scenarios covers 2014-40, and 2015 is the base year. Four scenarios are all based on the same main relevant macroeconomic assumptions. Detailed information of the macroeconomic assumptions is specified in Table 1.

In order to evaluate the performance of the iron and steel industry policies formulated by the Chinese government, every policy should be transformed into the parameter settings of the LEAP policy model. The detail assumptions and parameter settings of these four scenarios are shown in Table 2. For simplification, during the construction of the LEAP policy model, all inputs of every process are supposed to be determined by the requirement of the next process, and the demand ratios of two processes are considered to be constant. Based on this hypothesis, the intermediate products, such as sintering ore and pig iron et al., can be projected step by step.

Results and Discussion

Energy Consumption

Based on the key assumptions of China's economic development trend and specific assumptions on alternative scenarios, this section computed and analyzed the energy demand of different scenarios from 2015 to 2040 with the help of the LEAP policy model. Detail projected energy consumption data of all four scenarios can be seen in Fig. 5.

Energy consumption for all scenarios in China's iron and steel sector would decrease from 2015 to 2040. Energy demand decreases rapidly until 2025, and would be less quick during 2030 to 2040. In the BAU scenario, energy consumption coming from the iron and steel sector decreases from 13.9 billion GJ in 2015 to 12.5 billion GJ in 2040, which has a slow downward trend. The downtrend in three policy scenarios is more obvious than the BAU scenario and the total amount of energy demand declines a lot. In the CEC scenario, energy consumption decreases from 13.9 billion GJ in 2015 to 6.6 billion GJ in 2040. In the TI scenario, energy demand coming from the iron and steel sector decreases from 13.9 billion GJ in 2015 to 7.5 billion GJ in 2040. The greatest degree of decline emerges in the ET scenario and the energy demand under ET scenario decreases from 13.9 billion GJ in 2015 to 4.9 billion GJ in 2040. This means that the ET scenario has the least energy demand, and a most remarkable energy-saving effect.

As shown in Fig. 6, there is a comparison of energy demand between different scenarios. The base year is 2015, and therefore energy demand in 2015 is assumed to be 1. According to Fig. 6, this study is able to explore the energy-saving performances of iron and steel industry policies in different scenarios. Energy demand under CEC, TI, and ET scenarios are 0.46, 0.53, and 0.35, respectively, with a decreased ratio of 54%, 47%, and 65%, respectively, in 2040. This also means that there is great energy-saving potential in China's iron and steel sector.

In order to gain insight into the construction of energy consumption in alternative scenarios, this paper takes the ET scenario as an example. Coal and electricity power account for more than 97% of the total energy consumption in China's iron and steel sector. To simplify the analysis, this section analyzes coal and electricity consumption only. Fig. 7 shows the consumption of different types energies under the ET scenario. The changing tendency of consumption in coal is different from that of electricity. In the ET scenario, coal energy consumption is reduced from 12.7 billion GJ in 2015 to 3.7 billion GJ in 2040. The absolute amount of coal consumption decreases under ET scenario from 2015 to 2040, while electricity consumption fluctuates a little. Electricity consumption shows a slightly rising trend, and increases from 1.1 billion GJ in 2015 to 1.2 billion GJ in 2040. From Fig. 7 it can be seen that coal-related resources are still the major energy source in China's iron and steel sector. But with the government's encouragement of short process EAF-steelmaking, China's iron and steel industry structure is also adjusting constantly, and the dominant position of coal-related energy in the steel industry is also weakening gradually.

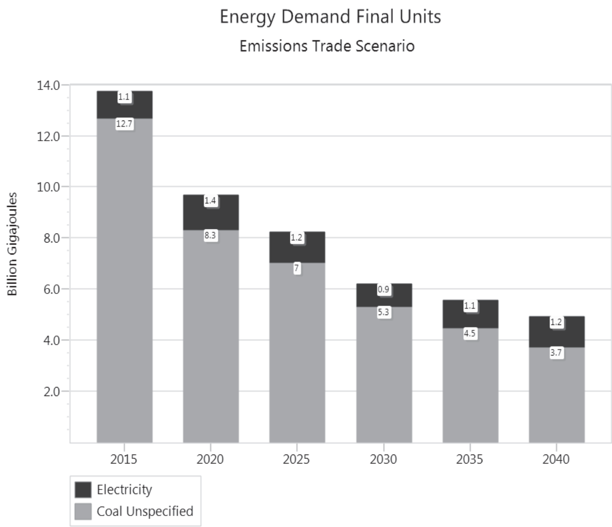

Fig. 7. Classification of energy consumption of ET scenario.

CO_2 Emissions

With the assistance of the LEAP policy model, this section evaluated energy-related CO_2 emissions of four different scenarios from 2015 to 2040. Direct and indirect CO_2 emissions of China's iron and steel sector are all included in the results. Electricity-related CO_2 emissions of the iron and steel sector are according to the average CO_2 emissions coefficient [27-29] of China's power generation.

As shown in Fig. 8, CO_2 emissions of China's iron and steel sector of all four scenarios descend gradually from 2015 to 2040. CO_2 emissions of the BAU scenario decrease from 1,271.6 million metric tons (MMT) in 2015 to 1,144.5 MMT in 2040, which shows a slowly descending tendency. The downtrend of three policy scenarios is more remarkable than the BAU scenario and the total amount of CO_2 emissions declines a lot. In the CEC scenario, CO_2 emissions decrease from 1,271.6 MMT in 2015 to 590.2 MMT in 2040. In the TI scenario, CO_2 emissions coming from the iron and steel sector decrease from 1,271.6 MMT in 2015 to 634.5 MMT in 2040. The ET scenario has the least amount of CO2 emissions, which decrease from 1,271.6 MMT in 2015 to 361.5 MMT in 2040, and show the most significant abatement effect.

In order to cast light on the detailed composition of CO_2 emissions in alternative scenarios, this section takes the ET scenario as an example. Fig. 9 shows carbon emissions of electricity- and coal-related consumption from 2015 to 2040 under the ET scenario. CO_2 emissions from coal consumption in the ET scenario decrease from 1,152 MMT in 2015 to 263.5 MMT in 2040. In China's iron and steel sector, carbon emissions coming from coal consumption decrease year by year, and it has a significant decline between 2015 and 2030. Carbon emissions coming from electricity consumption increased from 93.2 MMT in 2015 to 116.7 MMT in 2020. CO_2 emissions from electricity consumption in China's iron and steel industry will decrease a little from 2020 to 2030, and which shows an upward trend during 2030 to 2040, although it is a minor fluctuation. The reason for this trend is the increasing proportion of EAF steelmaking. With the development of the economy and technology, in order to meet the requirement of the national emissions reduction target, the increasing use of electric arc furnaces will drive electrical power demand in China's iron and steel sector instead of decreasing it.

Comparison of Policy Scenarios

In order to compare the effects of CO_2 emissions reduction between the iron and steel industry policies formulated by the Chinese government, this section

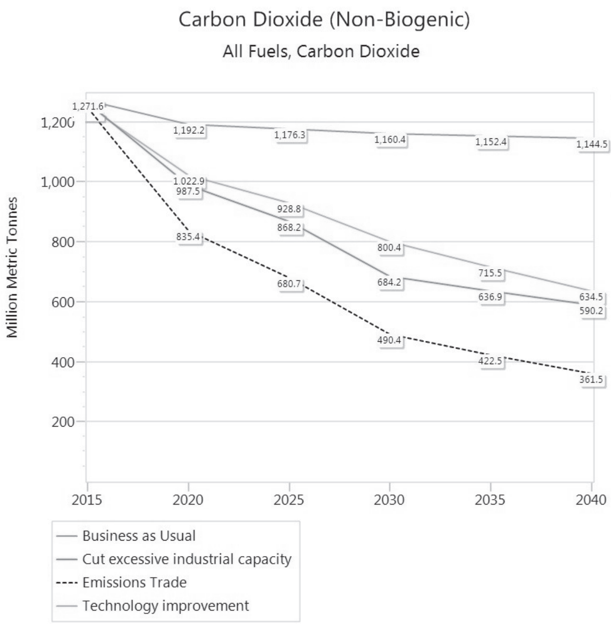

Fig. 8. CO_2 emissions under different scenarios from 2015 to 2040.

compares the CO_2 emissions of three policy scenarios using the CEC scenario as a benchmark. As shown in Fig. 10, CO_2 emissions in the TI scenario will increase during 2015 to 2030, and decrease after 2030 until 2040, compared with the CEC scenario. This means that policies of restraining production are more powerful than technology promotion policy when it comes to the effect of CO_2 emissions reduction before 2030. But it is also clear that, after 2030, the role of technology promotion is becoming more and more significant.

Compared with the CEC scenario, the ET scenario's CO_2 emissions decrease by 228.8 MMT in 2040. The ET scenario has the least CO_2 emissions among the three policy scenarios, and ET policy is the most effective policy on CO_2 emissions abatement in the iron and steel sector. The implementation of ET policy will make emission-reduction the core strategy of improving connotative competitiveness. Operating a carbon trading system will internalize the external cost of CO_2 emissions and, therefore, CO_2 emission reduction will be profitable. This invisible hand will help with guiding enterprises to run on the way of low-carbon, and recycle iron and steel production. As a market mechanism, the emissions trading market has three remarkable characteristics compared with administrative means and financial measures. First of all, meeting the absolute reduction targets in total is possible. Second, the emissions trading market makes it possible to guide the allocation of scarce resources through transparent, predictable, and real price signals. The third characteristic is it offers a highly efficient and low-cost emissions reduction method on a social level.

Conclusions

There are huge potentials for energy-saving and CO_2 emissions abatements in China's iron and steel sector. Energy demand and CO_2 emissions of China's iron and steel sector could be lowered by a large margin if relevant policies formulated by the Chinese government are implemented. Policies of China's iron and steel industry do much to help promote energy-saving and low-carbon economic development, but the performances of each policy are not the same. According to the effect of energy conservation and CO_2 emissions reduction, sequences of four scenarios from good to bad are the ET, CEC, TI, and BAU scenarios. This also indicates the sequence of policy effects.

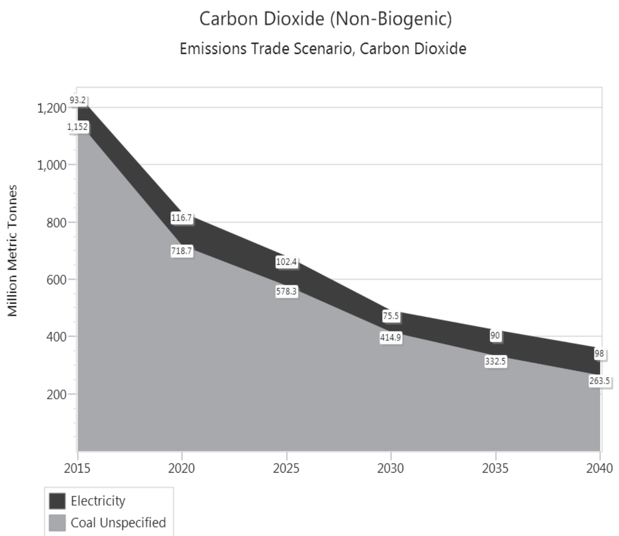

Fig. 9. Classification of energy-related CO_2 emissions of ET scenario.

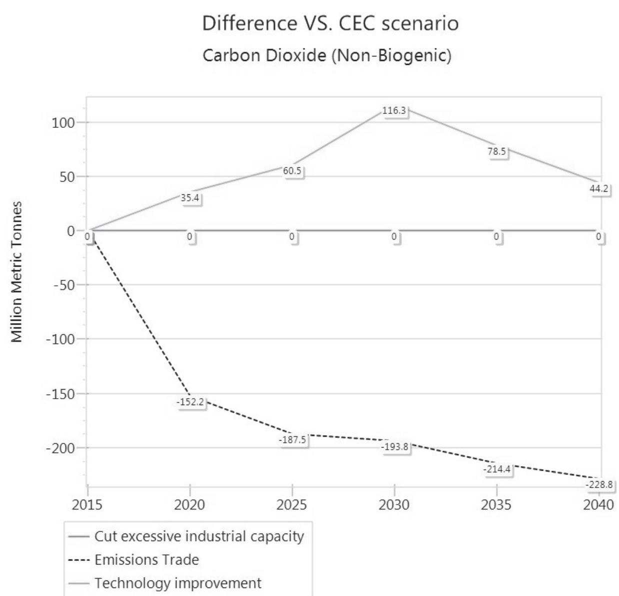

Fig. 10. CO_2 emissions of three policy scenarios compared with CEC scenario.

By controlling China's iron and steel production capacity, it is possible to solve the problem of overcapacity and reduce energy consumption as well as CO_2 emissions at the same time. Reducing the use of outdated production capacity could also improve the whole level of the technology to some extent. Overcapacity has already become a crucial issue that restricts the development of China's iron and steel sector. Therefore, the government should put in place a strict mechanism for closing down outdated production facilities. At the same time, iron and steel enterprises should take initiative to meet new normal economic development, and transform from depending on capacity expansion and price competition to innovation and quality promotion. China should also make full use of the guiding and restraining function of industrial planning, policies, and criteria in the iron and steel industry. Improving the information base of major project construction and an early warning mechanism should also be encouraged on preventing overcapacity.

Energy demand and CO_2 emissions could be well managed when China's iron and steel sector updates its technologies according to the guidance of the "National Key Energy Conservation and Low Carbon Technology Promotion List (2015)." Developing energy-saving technologies, introducing advanced technology from abroad, and popularizing sophisticated technologies in China's iron and steel sector are extremely necessary. The government should also improve and revise the industrial specifications continuously, and reinforce energy conservation and environmental protection index constraints in the iron and steel sector. Only in this way will it be possible to develop a low-carbon emissions iron and steel sector.

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