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Study on the Ecologic Network System of Energy-intensive Industries

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Abstract

The energy-intensive industries (including metallurgical industry, chemical industry, building material industry, and thermal power industry) come to form an ecologic network system based on the eco-industrial chains in the process of circular economic construction. This article tries to analyze and study the systematical elements, composition of eco-industrial chains and the model of network structure, in the view of integrated system. The construction of ecologic network system is an important way for the coordinated development of circular economy in an energy-intensive industrial cluster. Some suggestions are made to improve the ecologic network system comprehensively.

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1. Introduction

The energy-intensive industries generally refer to the traditional industries which process mineral resources primarily, with consuming a great many of energy and producing a lot of waste and environmental pollution. These industries mainly lie in the metallurgical industry (including nonferrous metal, iron and steel), chemical industry, building material industry and thermal power industry, which represents the gradual formation of energy-intensive industrial cluster (EIIC) [1]. However, the energy-intensive industries are the basic industries of our country, and are the fundamental fields of circular economy construction. Given the current economic and social condition, it is not advisable to limit their development, and to some extent a practical way to improve the effect of circular economic construction through the growth of industrial cluster. With the practice of EIIC on circular economy and its success,
we can find lots of eco-industrial chains are formed not only through the longitudinal extending along an industrial chain, but also by the crosswise coupling among industries. That is to say, the circular economic construction of each energy-intensive industry is not carried out on its own, but in a mutually influenced way, which demonstrates the trend of the formation of an ecologic network system. The ecologic network system of an EIIC also has an obvious and unique feature of an industrial cluster network system. Thus, in order to give a fully developed consideration of circular economic coordinated development for an EIIC on the perspective of promoting the ecologic network system, this article tries to analyze and study the structure of this particular network system through a systematic and structural analysis based on systematic elements, composition of eco-industrial chains and the model of network structure.

2. Analysis on the systematic elements of an EIIC

According to the system theory, systems are integrated through the exchange of substance, energy and information. The basic objective of the circular economic construction for an EIIC is saving energy, lowering consumption and reducing discharge. Saving energy includes lowering energy consumption and the second utilization of energy, which belong to the domain of energy exchange. Lowering consumption and reducing discharge mean to reduce, recycle and reutilize substance, and it is a process of material exchange. Saving energy, lowering consumption and reducing discharge are the process of information exchange as well, which consists of idea change, knowledge spread, technology innovation, rules making and etc.

Based on the production of energy-intensive industry, three basic elements (substance, energy and information) of industrial cluster system could be defined as below. (1) Energy. Energy consumption refers to coal consumption and electricity consumption. The second utilization of energy refers to the reuse of waste heat including heat gas, heat water and heat cinder. (2) Substance. We should reduce the consumption of ore and water, increase reutilizing by-products and water, and focus on recycling “three wastes”----waste water, waste gas and solid waste (slag). (3) Information. It includes production information, technology information, policy information, market information, rule information and etc. According to the structure model of a green integrated manufacturing system [2], there are seven compositive parts in the integrated system of EIIC, which are substance, water, energy, technology, information, public installation and firm. The order relationship of the seven parts is shown in Figure 1.

An integrated system of an energy-intensive industrial cluster

Top Parts
- Firms
  - Ore mining, dressing, smelting
- Public installation
  - Central heating, water disposal and etc

Middle Parts
- Substance
  - Ore, byproduct, three wastes
- Energy
  - Coal, electricity, waste heat
- Information
  - Technology, policy, market

Bottom Parts
- Water
  - Fresh water, disposed water, waste water
- Technology
  - High and new technology, green technology

Fig. 1. The order relationship of the systematic compositive parts of an energy-intensive industrial cluster
In Figure 1, first, water and technology are the bottom parts, which are the basic and special ones of the basic elements of substance and information. They should be analyzed and emphasized alone. Second, according to the seven compositive parts, some typical elements, parts or links in the system of EIIC are given. Third, the middle parts (general systematic elements) are integrated to form the top parts -- firm and public installation which is operated as a firm. And fourth, an integrated system of EIIC is integrated of the top parts.

3. The typical eco-industrial chains of an EIIC

The eco-industrial chains are the ties of an ecologic network system of EIIC, which are integrated by systematic elements. Below is the typical eco-industrial chains existed in the typical industries of EIIC.

3.1. The eco-industrial chains in the thermal power industry

A lot of three wastes are discharged from the thermal power industry, which are waste gases (SO₂, NOₓ, CO₂ and etc.), solid waste (cinder, ash, slag and etc.), and industrial waste water. The current eco-industrial chains have been built to utilize the desulphurized byproduct (desulphurized gypsum) and ash.

- Byproducts utilization industrial chain: coal—coal electricity—byproduct (desulphurized gypsum, ash)—building materials (cement, gangue brick, gypsum product and etc.)

In general, coal is classified, washed, and coked. Fine coal are used as the raw materials for smelting or chemical industry (see the part of coal chemical industry chain), and the inferior coal are used to generate electricity. The eco-industrial chain of inferior coal utilization is shaped thus.

- Inferior coal utilization industrial chain: raw coal—washed coal—inferior coal—to (coal mud, coal gangue)—electricity generation

The construction of eco-industrial chains in the thermal power industry is still in the primary stage since technology, policy, and market are far from perfect. Especially, the utilization of NOₓ, CO₂ and heavy metal in solid waste are in the exploring stage.

3.2. The eco-industrial chains in the metallurgical industry

Metal smelting is divided into that of ferrous metal and nonferrous metal. Production of iron and steel is the typical ferrous metal smelting, and production of copper is the typical nonferrous metal smelting.

3.2.1. The eco-industrial chains in the production of iron and steel

- Main industrial chain: iron ore—iron fine ore—sintering ore—iron—steel—mechanical processing
- Byproducts utilization industrial chain: iron ore—iron fine ore—sintering ore—iron slag—steel slag—building material
- Energy byproducts utilization industrial chain: coal—coke—coal gas, waste heat—energy

The construction of eco-industrial chains in the production of iron and steel is carried out widely in China. The problems are the energy and water consumption of unit product is still much more than that of the international advanced level.

3.2.2. The eco-industrial chains in the production of copper

- Main industrial chain: copper ore—copper fine ore—electro-copper—mechanical processing
- Rare metal utilization industrial chain: copper ore—copper fine ore—gold and silver byproducts
- Chemical byproducts utilization industrial chain: copper ore—copper fine ore—smelting—sulphur dioxide—sulphuric acid
- Energy byproducts utilization industrial chain: copper smelting—waste heat—energy

The construction of eco-industrial chains in the production of copper is carried out widely in China also, but the using rate of copper slag is much less than iron or steel slag.
3.3. The eco-industrial chains in the chemical industry

There are many sub-industries in the chemical industry, in them, the sub-industries relating closely with EIIC are coal chemical industry and phosphorus chemical industry.

3.3.1 The eco-industrial chains in the coal chemical industry
- Main industrial chain: fine coal — coking — coal gas — carbinol — fine chemical products
- Raw material for metallurgical industry industrial chain: fine coal — coking — metal smelting

3.3.2 The eco-industrial chains in the phosphorus chemical industry
- The main industrial chain: phosphorus ore — phosphoric acid, yellow phosphorus — fine phosphorus chemical products
- Phosphorus gypsum utilization industrial chain: phosphorus ore — phosphoric acid — phosphorus gypsum — gypsum building material, cement, sulphuric acid

3.4. The eco-industrial chains in the building material industry

The raw materials for the building material industry are diverse, including building material, non-metallic ore, and inorganic non-metallic material. The specific building material industries closely related with EIIC are cement, brick and roadbed material.

3.4.1 The eco-industrial chains in the production of cement
The ingredient of cement may include some solid wastes such as smelting slag, chemical slag, coal slag and etc. The waste heat from the production of cement may be reused also. So far, the slag used in the production of cement is still limited owing to their complex ingredient and disposing cost, as well as the incompleteness and imperfection of technology and policy.

3.4.2 The eco-industrial chains in the production of brick and roadbed material
Most of slag has been utilized as the materials for production of brick and roadbed material since the lower technology requirement. The value adding effect is less thus.

4. Building a model of ecologic network system for EIIC

The four industries have been linked together to form a network system through the above analysis of eco-industrial chains among EIIC. This network system is described as an ecologic network system usually. A model of this ecologic network system shown in Figure 2 is an abstracted version and given here to describe primarily the existed ecologic network relationship among the four energy-intensive industries of an EIIC. Several view points are stressed below.
- In the area of rich energy and mineral resources, it is a general way to develop energy-intensive industries actively through the integration of ore and energy. The mineral resources industries are becoming the mainstay of these areas. The environment is polluted seriously of course with a huge amount of slag indisposed. It is an inevitable choice for these areas to build the ecologic industrial chains of coal electricity — smelting — building material or coal electricity — chemical industry — building material with a great effort for sustainable development.
- There is a production process of high temperature burning for all the energy-intensive industries. The waste heat, which used to be discharged into environment, is asked to reuse for regenerated energy now. In such a way, the ecologic industrial chains of coal electricity — smelting — building material or coal electricity — chemical industry — building material is not only the extending of industrial chain, but also to form a closed industrial chain to some extent.
- The bidirectional byproduct exchanges have occurred between the metallurgical industry and chemical industry. For example, coke needed for the smelting production comes from coal coking. A huge amount of sulphur dioxide produced from the smelting process is retrieved to make sulphur acid which
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is an important middle product of chemical industry. The metallurgical industrial chain and chemical industrial chain are the main industrial chain in EIIC. The bidirectional byproduct exchange between them, which is weak now but may be improved in future, is of great importance to promote the ecologic network system of EIIC.

5. The promotion of the ecologic network system for EIIC

The ecologic network system of EIIC is on the primary stage till now. To promote it, we discuss from three aspects or levels below.

- On the aspect of the systematic element of an EIIC. The key points of circular economy construction are saving energy, water reusing, comprehensive utilization of mineral resources, three wastes disposing and etc, which have been emphasized quite a lot in the practice. Many periodical successes have been achieved till now. To be noticed, the works on the information elements such as green technology, green system innovation and market incentive mechanism have not been paid enough attention yet. There exists some structural obstruction to be overcome. According to the industrial cluster theory, gathered industries may improve and promote the shape and spread of district innovation system [3]. The gathered energy-intensive industries are scattered generally so far, this is a structural obstruction to spread information. Therefore, local government should provide space environment and policy for the gathering of energy-intensive industries, so as to promote the technology and system innovation and spread of circular economy, and to bring about the fundamental condition for the coordinated development of circular economy of an EIIC.

- Regarding to eco-industrial chain construction of an EIIC. The quantity and quality of eco-industrial chains are the important and determinative factors for the gathering of energy-intensive industries. The basic ways to promote the construction of the ecologic network system is: firstly, the diverse eco-industrial chains are built, replenished and improved; secondly, longitudinal extending and lateral coupling are combined and interweaved; thirdly, the interweaving of the eco-industrial chains should be in order, that is to be carried out on the base of the main industrial chain, considering the stage and key points. For the ecologic network system of EIIC, some detailed thinking and suggestions are, first, the desulphurizing eco-industrial chain in thermal power industry has been attached great importance to construct, while the situation of decarbonating eco-industrial chain is still fallen behind, which have to be sped up to meet the demand of the low-carbon economy development in the world. Second, in the construction of eco-industrial chain in metallurgic industry, to lower the energy consumption of
iron and steel is the key problem, and the more ore slag of nonferrous metal have to be utilized. Third, in the construction of eco-industrial chain in chemical industry, the extension of fine chemical product industrial chain is the key problem of technology strategy; except for coal slag, the utilizing rate of other nonmetal ore slag is still low. And fourth, utilizing diverse and more ore slag to replace the raw materials is the direction for the building material industry to make improvements.

- As to ecologic network system construction for EIIC. To coordinate the economic economy construction process of each energy-intensive industry is an important and basic way to promote the ecologic network system for EIIC. The objective of the coordinated development is zero discharge of three wastes through internal structure adjustment and reorganizing. This is a long term task. The current works are the united production of thermo-electricity, mutual benefit and symbiosis among an EIIC, the inter-industrial transforming and reusing of byproduct and waste and etc [4].

6. Conclusion

Under the current economic and social condition of our country, the energy-intensive industry lies in the fundamental position, and is the pillar industry in the central and west region of China. Although it has the features of high energy consumption and high pollution, its position may not be changed in a long term period. It is worth heartening that, the ecologic network systems among the energy-intensive industries have come to shape gradually with the construction and progress of circular economy in each energy-intensive industry. The characteristic of an industrial cluster is appearing in the gathered energy-intensive industries. The progress of the ecologic network systems among the energy-intensive industries is a process of coordinating the construction of circular economy in each energy-intensive industry actually. It will both improve the economic effect and ecologic effect of the gathered industries to reach the two win, and may reduce greatly the negative effect of developing the energy-intensive industries. To study the ecologic network system will be the basis of probing the coordinated development of circular economy for an energy-intensive industrial cluster. To construct the ecologic network system of an energy-intensive industrial cluster, three aspects or levels of works have to be done. First, on the macro aspect, it is significant to attach great importance to the coordinated development of circular economy for an energy-intensive industrial cluster. To construct the ecologic network system of an energy-intensive industrial cluster, three aspects or levels of works have to be done. First, on the macro aspect, it is significant to attach great importance to the coordinated development of circular economy for an energy-intensive industrial cluster. Second, on the middle level, it is necessary to build and replenish diverse eco-industrial chains. Third, on the micro aspect, it is worth notice to adjust and optimize the ecologic position of each systematic element, so as to shape up the justified and improved systematic structure.

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