

Study of Green Information Disclosure on China's Thermal Power Plants

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Abstract. This paper studies the way of green accounting information disclosure by introducing the basic idea of input-output analysis and combining it with the energy analysis in the field of ecological economics and aims to explore a framework to disclose green accounting information. Firstly, through the research on the status quo of China's green information disclosure, it is found that there are two main problems in the disclosure of green information in China, that is, incompleteness in disclosure content and difficulty in measurement. Then, by taking China's coal-fired thermal power generation as an example, the main input resources, flow of directions and the final transformation forms are summarized from the perspective of material flow. By analyzing the generation process of coal-fired generation plants, this paper attempts to apply the basic idea of input-output analysis to construct the preliminary framework of green information disclosure. Furthermore, energy analysis is introduced to convert physical data to monetary information to provide a unified enterprise disclosure framework of green accounting.

1. Introduction

With the development of the global economy, China has entered a new era. Before 1970s, China's environmental problems were neglected because of the priority of quick success and instant benefits on economic progress and lack of environmental protection policies [1]. However, Chinese environmental development is no longer a mere economic progress recently, ecological development has also been elevated to a strategic level and has become one of the most important goals in which China pursues. The 18th National Congress of the Communist Party of China proposed the five-in-one strategic layout. Before that, four-in-one layout has played a dominant role for the past decade which was made up by economic construction, political construction, cultural construction and social construction. Compared to four-in-one layout, ecological civilization construction is brought into five-in-one layout and become China's strategy for the first time. The requirements of coordinating ecological development and economic development make the enterprises pay increasing attention to social responsibilities while pursuing the goal of maximizing profits. The point is that they should shoulder social and environmental responsibilities [1]. The traditional accounting has been strongly influenced by new ideas. A growing number of countries have added the content of environmental information disclosure under the traditional accounting information disclosure framework [3]. Green accounting is a tool of recognition, collection, and analysis of environmental information which is

also known as environmental management accounting (EMA) by the international community [4]. The researches of F A Beams [5] and J T Marlin [6] on the social costs of pollution and the accounting of pollution have created a new era of green accounting and researches on green accounting have begun to grow.

The United Nations released the System of Integrated Environment and Economic Accounting (SEEA) [7] in 1993. As a product of the sustainable development economy, it is mainly used for the implementation of national accounts under the influence of environmental factors. Afterwards, the UN Department of Public Information Strategic Communications Division (UNSD) put forward specific methods for implementing environmental management accounting [8]. The UNSD EMA method includes four types of environmental expenditures (costs) and one type of environmental income measured by seven environmental media. By the implementation of this classification, companies can find hidden costs and relevant cost savings. Since then, Gale [9] applied this method to a Canadian manufacturing company and found that the natural and environmental costs under traditional accounting were underestimated by approximately 50%.

As the topic of corporate social responsibility continues to intensify, more and more scholars begin to pay attention to the relationship between organizational behavior and the environment [10]. One study found that environmentally sensitive organizations such as mining, chemical, pharmaceutical and oil extraction are more likely to implement green accounting, while legal requirements also force these industries to actively use environmental accounting as a method of internal management [11]. Moreover, due to the limitation of organizational capital, the effective utilization of environmental resource capital also urges managers to pay more attention to environmental strategy [12]. In addition, the strategic direction of the enterprise, the industry in which it operates and the size of the organization also have a great relationship with the use of environmental accounting [13]. However, although green accounting has received growing attention, its application still faces many difficulties, lack of learning at the organizational level, excessive attention to economic performance and lack of guidance on the application of environmental accounting [14] have seriously hampered the development of green accounting.

China entered the ranks of the newly industrialized nations (NICs) in 2011, and the contradiction between economic growth and environmental development has become increasingly prominent [15]. Recycling economy and green economy have become the theme of the development of new era. The demand for green information is increasingly highlighted [16]. In the 1990s, Jiashu Ge [17] introduced the concept of environmental accounting into China for the first time, marking the beginning of China's systematic study of green accounting. So far, theorists have tentatively set up the theoretical framework of green accounting [18] and pointed out that enterprises are facing serious environmental risks and environmental liabilities [19]. However, there are only few studies on the methods of green information disclosure in China. At present, the disclosure of green information draws basically on traditional financial accounting and generates a series of forms such as environmental balance sheet, environmental cash flow statement and environmental profit statement [20]. However, there is no further study on how to quantify the green information which is of vital importance in the information age.

What kind of green information should organizations disclose to the general public? How to quantify the green information to make it more comparable? By analyzing the current situation of China's green accounting information disclosure, this paper attempts to use the basic idea of input-output analysis to build the preliminary framework of green information disclosure, taking the coal-fired thermal power plant as an example. Also, by introducing the theory of emergy analysis into the framework of green information disclosure, this research may help to solve the problem of the current measurement dilemma of green information.

2. Green information disclosure in China

The demand for green information is the main motivation for enterprises' disclose behaviors. Although an increasing number of public listed companies in China have disclosed Corporate Social Responsibility Report (CSR) in order to meet the economic decision-making needs of stakeholders [21] in recent decades, the performance of environmental and social responsibility information in the report is not enough to satisfy the needs of the public. Therefore, this paper studies the status quo of Chinese corporate green information disclosure to find out the main problems existing in the green information disclosure, and attempts to put forward effective solutions.

2.1. *The institutional background of green information disclosure*

The 1989 Environmental Protection Law stipulates that the government's environmental protection authorities shall regularly public environmental accident reports (article 11). Projects that endangering the environment must firstly submit environmental impact assessment reports to environmental authorities(article 13). The 1989 Environmental Protection Law can be regarded as a preliminary exploration of environmental information disclosure, but it is limited to a one-way enterprise-government disclosure pattern. Although the 1989 Environmental Protection Law regulates that enterprises should bear legal responsibility for environmental pollution, it lacks explicit requirements on green information disclosure.

In the year 2015, Chinese government issued a new "Environmental Protection Law of the People's Republic of China" in response to a series of problems facing China's environmental protection in the new era. The environmental protection supervision and management work has officially become the examination content of government staff and the result of the examination will be disclosed to the social public (article 26).Also, the government shall promptly assess the environmental impact and losses for potential environmental and release the result to the social public (article 47). The law also adds a separate chapter on information disclosure and public participation, emphasizing the importance of public disclosure of environmental information. However, the new Environmental Protection Law only requires enterprises to disclose the discharge and treatment of major pollutants, no specific guidelines on information disclosure have been issued, resulting in the lack of comparability of environmental information disclosed by industries.

2.2. *Practice of green information disclosure on enterprises*

Table 1. The main content of green information disclosure.

Item number	Content
1	Environmental protection guidelines, annual environmental protection objectives and achievements
2	Total annual resource consumption
3	Information on investment of environmental protection and environmental technology development
4	Type, volume and content of pollutants discharged and where the pollutants are discharged into
5	Information on the handling and disposal of waste generated from production Information on recycling and comprehensive use of waste products
6	Information on the construction and operation of facilities
7	Voluntary agreement with environmental protection departments
8	Information on performance of social responsibilities
9	Environmental information voluntarily disclosed

The current green information disclosure forms of listed companies in China mainly include annual report, CSR report and environment report. Environmental Protection Administration of China promulgated the "Measures on Open Environmental Information" to encourage enterprises to voluntarily disclose the environmental information and heavy polluting enterprises mandatorily demanded to disclose environmental information. Enterprises should announce to public that the company follows the relevant environmental protection guidelines, company's annual environment protection goals and achievements, annual resource consumption, etc., as shown in Table 1:

With the exception of heavily polluting enterprises, companies in other industries tend to use environmental disclosure as a selective strategy because they have no mandatory requirements. As a result, they only disclose information that helps to enhance their corporate image and create a reputation for their business [22]. In selecting the content for disclosure, they are preferable to give priority to publicizing information on environmental benefits and social responsibility to the general public, and to guide the information audience to focus on the positive output produced by enterprises. This kind of merit-based selection behaviour of enterprises leads to the incompleteness of green information disclosure content and the non-uniform form of disclosure. After a series of production processes, a company's products are usually accompanied by negative environmental outputs, such as sewage and exhaust emissions in addition to products flowing into the market that have a realizable value. These negative outputs eventually flow to the natural environment and need to be governed thereby with a large amount of expenditures which makes up the environmental cost of enterprises. Environmental cost standing at the last link of the production chain is often ignored by enterprises [23], and rarely reflected in the environmental report, resulting in an imbalance between input and output.

Most enterprises disclose green information mainly in the form of narratives, lacking descriptions in physical quantity and market value. So the information disclosed by different enterprises lacks comparability. Some researches have studied the quality of corporate social responsibility reports issued by China's transportation industry and found that over 80% of the reports failed to achieve their aims. One of the reasons is that there is no comparability between reports [24]. Some scholars use computers to extract and classify the diction of green information disclosed by the enterprises, then measure the quality of green information disclosure from the perspective of semantic analysis and find that the industry, property rights and geographical areas will reduce the comparability of corporate green information disclosure [25]. The reason why the above problems arise is mainly due to the difficulty of quantifying green information while it is easier for enterprises to describe what laws and regulations they have followed in protecting the environment, what kinds of green investment projects are carried out, but the extent and value of such items are difficult to measure.

In this paper, the basic idea of input-output analysis is combined with the emergy analysis from eco-economics is introduced to solve the problem of measurement and disclosure of green accounting information theoretically. The input-output analysis is mainly used to define the content of green information which is easily understood when illustrating the disclosure framework of green information. Emergy is a type of certain energy stored in another kind of energy. Each substance is formed by a specific kind of energy, and each kind of energy can be converted into the same unit of measurement (solar emejoules) by energy transformity. The introduction of emergy analysis aims to solve the problem of measurement dilemma and incomparability of various sorts of information. This paper attempts to put forward a full input-full output-full information coverage disclosure framework to provide potential references for enterprises to disclose green information.

3. Green information disclosure framework based on China's coal-fired thermal power plants

As one of the main energy consuming country, China's coal-fired thermal power occupies an important position in the national economic field. Although the government vigorously advocates clean energy generation in recent years, due to the limitation of capital and technical conditions, coal-

fired thermal power generation still plays a dominant role. Besides, coal-fired thermal power generation has a huge impact on environment especially for its pollutant emission. Therefore, this paper takes coal-fired thermal power generation as an example to discuss the application input-output framework of green accounting information disclosure.

3.1. The basic idea of input-output analysis on green accounting

Input-output analysis [26] is a quantitative analysis of the interdependence of inputs and outputs among various parts of an economy. It can be applied to the entire national economy as well as corporations or specific corporate sector. Input refers to the consumption of raw materials, labor, machinery and equipment consumed during the production and business activities. Output refers to the distribution of products after the production process. Application of input-output analysis can intuitively reflect the internal links of production and operation between various departments of enterprises. The core idea of input-output analysis in this research can be summarized as substance conservation, that is, all inputs are outputted in a certain form.

The input and output is imbalanced in modern financial accounting to the aspect of confirmation, measurement and accounting [27]. Modern financial accounting only contains the cost of monetary item for the measurement of input, but ignoring the cost of environmental resources. Meanwhile, in the determination of output, financial accounting only confirm the economic value of the product, but neglecting the harmful products, resulting in an imbalance between input and output. Green accounting aims to make up for the lack of two deficiencies mentioned above. As shown in Figure 1, the main difference between green accounting and financial accounting lies in the scope of its accounting object. Accounting objects for financial accounting include resources available for production and operation such as raw materials, human resources, machinery and equipment, capital investment and other quantifiable resources. Output of financial accounting mainly targets in positive products that eventually enter to the market and help the organization to obtain profits. The object of green accounting is more extensive, it reflects the use of environmental resources, such as sunlight, air, surface soil loss, etc. At the same time, green accounting also deals with environmental pollution of the negative products as well as some neutral products which ultimately discharge into the natural environment but the degree of damage is not clear.

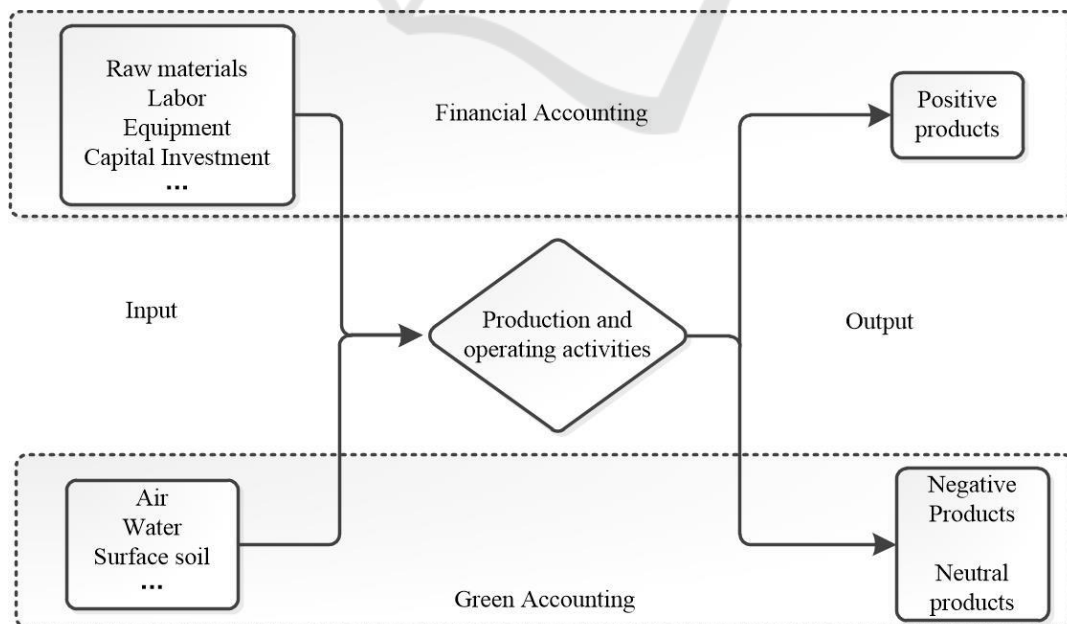


Figure 1. The main difference between green accounting and financial accounting.

Input-output analysis under the green accounting is a full input-full output-full coverage of information disclosure method. All resources invested by the enterprise should be outputted in a certain form. For example, coal is the main raw material inputs of coal-fired power plant which contains largely of carbon. The final product of coal-burning is disclosed in the form of electricity energy under the traditional financial accounting framework. However, the carbon element should also be discharged as CO_x and eventually emitted to the environment. Although some enterprises have already mentioned their contributions in regard to the energy conservation and emission reduction in the annual report, the disclosure is confined to describing whether the emission of CO_x is excessive and no specific emission quantity is released. The green accounting approach studied in this paper aims at using a full coverage information disclosure way to guide enterprises in disclosing all inputs and outputs so as to achieve a substantial balance between investment and production.

3.2. The main input and output of coal-fired thermal power plants

For the application of input-output analysis on green information disclosure, it is necessary to understand the production and operation process of all input resources and all output products. This paper simplifies the generation process of coal-fired thermal power plant from the perspective of material flow and summarizes the main input items, the flow of direction and the final transformation forms, which lays the foundation for the green information disclosure.

Coal-fired power plant involves four kinds of energy conversion. As shown in figure 2, the chemical energy of the fuel is firstly transformed into heat energy after being burned in the boiler. Then, the water absorbs heat energy and becomes steam to drive the steam turbine to generate mechanical energy. Finally, the generator produces the final product, electric energy.

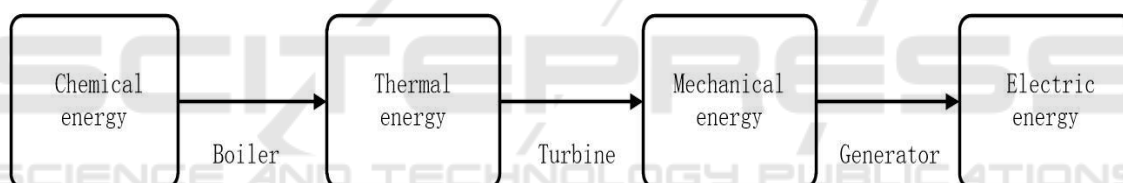


Figure 2. The energy conversion of coal-fired thermal power generation.

Figure 3 shows the main generation process of coal-fired power plants in China. The main input resources, flow of directions and the final transformation forms are summarized from the perspective of material flow. The dotted line in the figure divides it into two parts, with the left side demonstrating the main input resources and the right side displays the output products. Due to the diversity in the scale and equipment among different coal-fired thermal power plants in China, the resource conversion efficiency is uneven. Therefore, this paper assumes that all the input resources are 100% converted into output in order to theoretically explain the feasibility of the application of input-output analysis in the green information disclosure.

During the preparation work, coal is pulverized and mixed with air in order to make it sufficient burning. After that, pulverized coal is sent into the boiler as shown in path ① during combustion process in which generating heat energy. Heat then converts water into water vapor to drive the steam turbine. Finally the turbine drives the generator to generate electricity which is mandatorily disclosed in the corporate annual report as the main source of revenue.

In addition to electrical energy, a large number of by-products are contained in the gas generated by the boiler. Those by-products are mainly composed of dust, coal cinder and harmful gases (SO_x , NO_x , CO_2) which are permitted to discharge only after a series of environmental governance equipment such as desulfurization device, denitration device and dedusting device. Currently, coal-fired thermal power plants mainly use dust collector to control fly ash pollution, remove sulfur in flue

gas with desulfurization device, and reduce the formation of nitrogen oxides through the reasonable design and operation of the boiler.

One of the results of coal burning is the generation of SO_x , of which SO_2 will have a great harm to the environment. SO_2 is the main cause of air pollution and acid rain and for now flue gas desulfurization is considered as the most effective way to control the pollution of SO_2 . As shown in path ②, the limestone powder is used to wash the flue gas so that the two substances can react to remove SO_2 and ultimately produce gypsum which can be comprehensively utilized without secondary pollution. Besides, a small part of incompletely reacted SO_2 will be emitted to the air. In addition to SO_x , there is a large amount of NO_x contained in the boiler gas because of coal combustion. The NO in the flue gas can be oxidized into NO_2 after being discharged into the atmosphere, which is very harmful to the human body. As shown in path ③, at present, the catalyst and certain reductant is mainly used in China to converse NO_x in the flue gas to N_2 and H_2O , thereby reducing the pollution of the environment and releasing only a tiny amount of NO_2 into the atmosphere. In addition, the slag and ash generated by coal-fired thermal power plants can be transported to the ash field for secondary utilization after specific treatment, as shown in path ④. Also, coal combustion produces large amounts of CO_2 and soot as shown in path ⑤. CO_2 emissions from boilers account for about 30% of China's carbon dioxide emissions which becomes the main reason for the global warming. At present, the relevant department is actively implementing energy saving and emission reduction measures to control the emission of CO_2 .

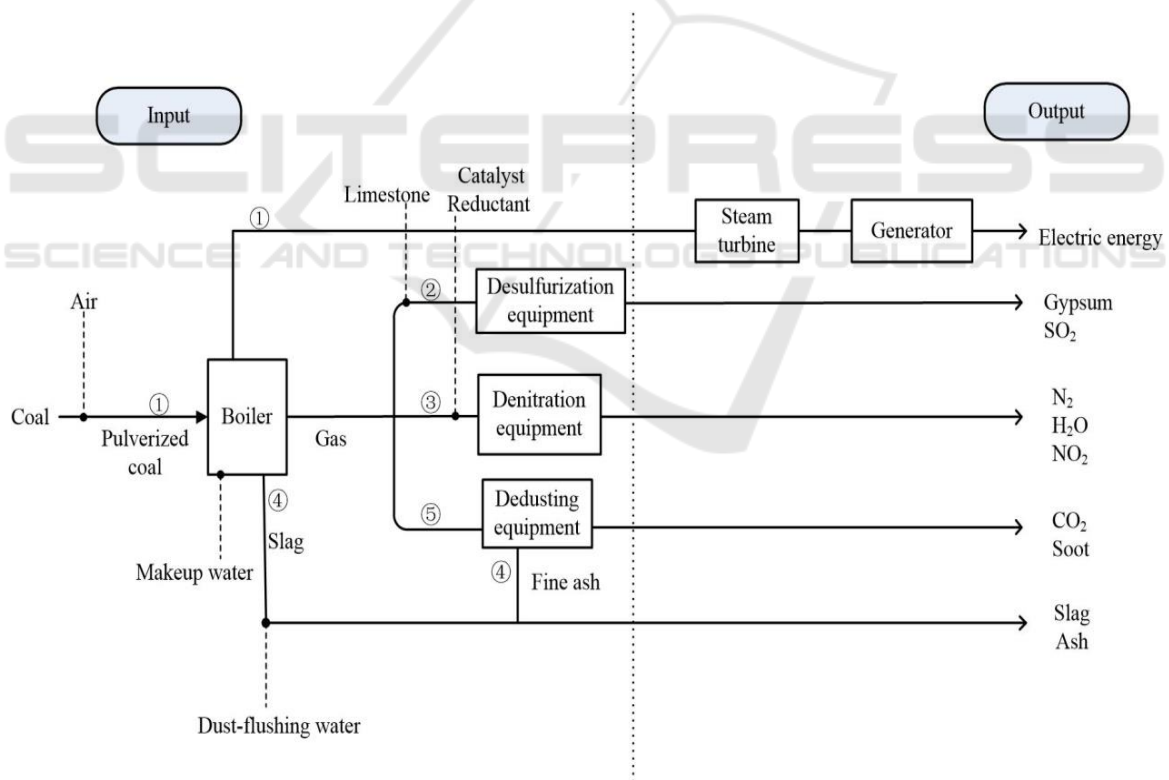


Figure 3. Main generation process of coal-fired power plants.

3.3. Green information disclosure framework of coal-fired thermal power plants

After defining the production process and resource consumed of an enterprise, it is necessary to make a comprehensive green information disclosure. Under the principle of input-output analysis, the total

input of an enterprise is equal to the total output. Although these outputs are not necessarily market-product-specific, they should also be disclosed about their subsequent processing, especially those that have a negative impact on the environment and require further tracking by enterprise until the substance enters in nature with minimal impact. Only in this way can the company's green mission be seen as terminated. Figure 4 shows a preliminary framework for green information based on the idea of input-output analysis with the example of coal-fired thermal power enterprises.

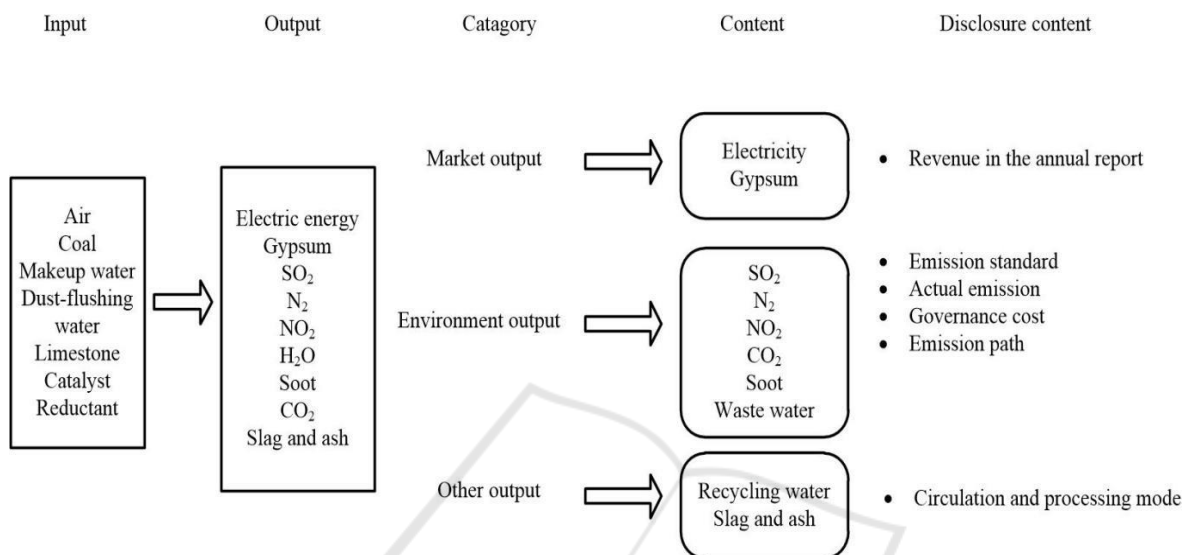


Figure 4. Green information disclosure framework of coal-fired thermal power plant.

On the disclosure of green information, enterprises firstly need to illustrate all the inputs and outputs in order to facilitate information audiences to understand the whole production and operation process of enterprises. This is also an initial step to achieve full input-full output- full information coverage objective. Taking coal-fired thermal power plants as an example (assuming that the resource conversion efficiency is 100%), as shown in Figure 4, inputs include air, coal, etc. while outputs refers to electricity, gypsum, etc. All inputs are outputted in a corresponding form.

From the perspective of information disclosure, the total output of enterprises can be divided into three categories: market output, environment output and other output. Market output means output flowing to the market. Environment output means output flowing to natural environment and other output means output flowing in other directions.

For market output such as electricity and gypsum, enterprises can make quantitative information disclosure in the annual report. Such output secedes from the enterprise information disclosure process since the sale to a third party, and the financial disclosure mission of the enterprise is terminated.

For environment output such as N₂, CO₂, SO₂, soot and a portion of waste water, companies need to disclose the implementation situation of emission standards, actual emissions, governance costs and emission paths to prove that this part of the environmental output being reasonable followed up. This also reflects the corporate performance of environmental and social responsibility. When these emissions are finally disposed into the environment and enter into the natural circulation, the green mission of the enterprise is terminated.

For other output such as recyclable water, slag and ash temporarily stored, companies need to explain the circulation and processing mode.

4. Application of energy analysis on green information disclosure

The construction of green information disclosure framework aims to initially solve the problem of incompleteness and inconsistency of green information disclosure. However, in the era of big data, there is a strong demand on quantitative information. The traditional disclosure of green information is based on the "discharge list" of emission standards set by the relevant departments, which only lists the emission of harmful substances. However, because of the differences in units of measurement between different emission sources, there exists a lack of comparability on various data. In response to this problem, this paper introduces the method of energy analysis in the field of ecological economics in order to solve the problems encountered in the measurement of green information.

4.1. Introduction of energy analysis

Emergy analysis is a theory of ecological economics proposed by H.T. Odum [28]. Emergy refers to a type of certain energy stored in another kind of energy. Emergy analysis assumes that any form of energy originates from solar energy, so all kinds of energy in the natural environment can be measured in a unified unit which is solar emejoules (sej). In the eco-economy, all sorts of energy and materials with different units can be converted into the same unit of measure through emergy transformity so that they can be quantitatively measured and compared to analyze the real benefits of environmental resources.

Emergy theory regards the ecosystem as a self-organizing energy system which is similar to the flow of the food chain. The energy is accompanied by a certain amount of loss at every stage of economic production. Therefore, as the energy goes from a low level (solar energy) to a high level (consumer energy at different stage of conversion), the amount of energy showed a declining trend, while the energy level is increasing. In an eco-economic system, the energy flow always flows from a low energy level (such as solar energy) to a high energy level (such as electricity) [29].

4.2. Application of energy analysis on green information disclosure framework

One of the biggest problems in green accounting when disclosing information is the inability to quantify the resources. The use of emergy theory may help to solve this problem. Although all the inputs and outputs have been summarized in the green information disclosure framework shown in Figure 4, the units for various kinds of substances are different (for example, coal is measured in tons and wastewater is measured in cubic meters), resulting in the lack of comparability between them which is not conducive to evaluate and compare enterprise's environmental protection performance. Therefore, as shown in Figure 5, after obtaining all the input and output data information of an eco-economic system, resources of different units can be first converted into solar emejoules. This step needs to use the emergy transformity as a conversion intermediary. Emergy transformity is the amount of another energy contained per unit of a material or energy. In emergy analysis, the commonly used transformity is solar transformity which is the the amount of solar energy contained per unit of a material or energy. The solar transformity increases as the energy level increases.

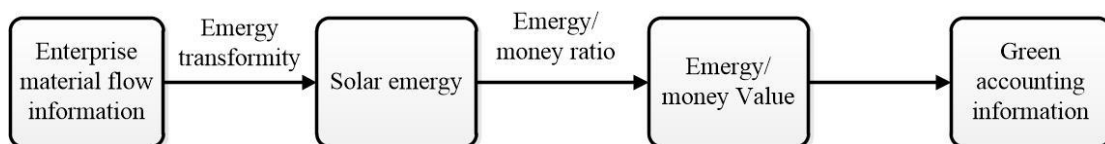


Figure 5. Application of energy analysis on green information disclosure framework.

After converting the physical consumption into the same unit through the conversion of the emergy transformity, the solar emejoules obtained is still a material unit and cannot become the

financial information commonly understood by the majority of investors. Therefore, further conversion through the emergy / money ratio is required. The emergy / money ratio is the ratio of the total annual energy value of a country or region divided by GDP of that country or region in a year. The higher the ratio, the greater the emergy wealth can be exchanged by the individual units, the greater the proportion of natural resources made up in the national economy. This often indicates that the country or region has a strong dependence on environmental resources, and such features are usually found in the extensive economies [30].

As shown in figure 5, it is known that the solar emejoules of a certain substance can be converted into the corresponding monetary value, that is, quantified green accounting information through the emergy /money ratio. Thereby, investors can be conducted to compare various resources consumed by an enterprise through unified calculation of different kinds of results. It should be noted that the monetary value is different from the currency used in traditional financial reports. The value of the monetary value in emergy analysis refers to the equivalent market value of the currency rather than the actual cost of purchasing such resources.

5. Conclusions

As an emerging branch of management accounting, the implementation of green accounting mainly focuses on the disclosure of green information. However, although the concept of green accounting has been proposed in China for a long time, there is a lack of a unified framework and method to apply green information to the practice of enterprises.

This paper aims to combine the basic idea of input-output analysis, take the green information disclosure of China's coal-fired thermal power plants as an example, apply the method of emergy analysis from ecological economics to the disclosure of information in green accounting and try to provide a unified enterprise disclosure framework of green accounting. First of all, through the research on the status quo of China's green information disclosure, it is found that there are some problems in the disclosure of green information in China, such as incompleteness in disclosure content and difficulty in measurement. In view of the above dilemma, this paper puts forward a tentative idea of setting up a green information disclosing framework by using the input-output analysis. After making clear of the production process and material inputs and outputs of an enterprises, this paper attempts to set up an information disclosure framework with full input-full output-full information coverage assumption. In addition, for the measurement of green information disclosure, this research introduces the theory of emergy analysis from eco-economics into the framework of green information disclosure and attempts to convert all input and output substances into a unified unit of measurement in order to evaluate the green information preferably.

However, this article also has some shortcomings in the method of the research. Taking the Chinese coal-fired thermal power generation plants as an example, the green information disclosure framework set up in this paper may have some omissions in the recognition of input and output substances due to professional constraints when taking the Chinese coal-fired thermal power generation plants as an example. Such defect may cause some scalability of the disclosure content of green information. Secondly, this paper proposes that emergy analysis method can measure all the input and output of enterprises theoretically. However, this method has not been widely used in China at present, and the data collection needs a lot of costs. Therefore, its application effect needs to be further studied.

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