Doctoral Dissertation

DEVELOPMENT OF THE EVALUATION INDEX SYSTEM AND COMPREHENSIVE EVALUATION OF ECO-INDUSTRIAL PARKS AND ENTERPRISES AS CIRCULAR ECONOMY

Graduate Programs in Environmental Systems

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Symbolic Interpretation

A_i: The index of target layer (i=1,2,3,…,n)

Bi: The index of criterion layer (i=1,2,3,…,n)

Ci: The index of state layer(i=1,2,3,…,n)

Mi: The index of variable layer (i=1,2,3,…,n)

a_{ij}: The importance of individual index A_i compared to A_j (i,j=1,2,3,…,n).

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Abstract

Eco-industrial park as a new industrial park combining the concept of circular economy and industrial ecology principles of construction, has not only become an effective way to achieve sustainable development, improving energy efficiency and the ecological environment quality in many countries, but also become an important carrier of implementing science-based, adjusting the industrial structure, accelerating the transformation and upgrading and constructing ecological civilization in China. China started construction of eco-industrial demonstration park pilots in1999, subsequently have actively carried out the practice of building eco-industrial park in nationwide, so far, the country approved the establishment of 62 national eco-industrial parks(EIPs) construction pilot units, of which 51 are integrated eco-industrial park, accounting for 82% of the total. Although the EIPs have made great progress in terms of planning and construction, and achieved some success in improving energy efficiency, reducing environmental pollution and improving environmental quality, but there are many problems in the development process, which restrict the stable operation and coordinated development and continuous improvement of the park, such as weak ecological relevance between enterprises, low resources and energy output rate, imperfect organizational structure, unclear construction goals and insufficient technical innovation. The causes of these problems are mainly due to the government agencies and park management department not paid enough attention to the coordinated development degree of EIPs, lacking of a practicable index system and assessment method for assessing the degree of sustainable development and comprehensive development level, which result in unable to fully grasp the operational state of the park and also can not formulate highly appropriate development strategy.

This paper, based on domestic and abroad development of EIPs, focused on the theory and methods of constructing the index system of EIPs, established the degree of coordination and comprehensive development level index system and evaluation

methods of sector-integrate eco-industrial parks(SIEIPs), specific research includes the following three aspects:

Firstly, reviewing the status of domestic and foreign research and development of EIPs, at the same time, over viewing several relevant theory and methods of construction of evaluation index system of EIP.

Secondly, drawing on the ideas of AHP and taking the coordinated development degree and the comprehensive development level as the overall evaluation goal of SIEIPs, from economic development, resource utilization, environmental protection, ecological civilization, park management, social progress six subsystems proceeding to considerate the current situation, construction effect, stability of development, sustainability and coordination of SIEIPs development, then use frequency statistics and expert consulting methods initially select several evaluation index, further superimposed on the primary indexes analyzed, screen and ultimately fix the evaluation index system of SIEIPs.

Lastly, multi-level extension comprehensive evaluation method is applied to build the model of coordinated development degree and integrated development level of the SIEIPs, and use this model to evaluate TEDA Eco-Industrial Park. The results show that the coordinated development degree of TEDA EIPs is weak, belong to weakly coordinated, the comprehensive development level is not high, belong to weak circulation. Therefore TEDA will have to make more effort to go into the stable and sustainable development of circular economy status. In addition, the evaluation results are factor analyzed, proposing strategies and measures to improve.

On the other hand, combining with the current development in China, enterprises independent of integrated industrial parks in many regions play an important role in the local economy. The methods for evaluating these enterprises are different from those in industrial parks. Therefore, it is necessary to construct a set of well-designed, operational evaluation index system. Enterprise as the basic unit of social and economic development, the implementation of circular economy for the regional and national implementation of circular economy has important influence. In order to better and faster to promote enterprises to develop circular economy, the enterprise's economic benefit, social benefit and ecological benefit evaluation enterprise circular economy as the basic starting point of the implementation effect, exploring enterprise of circular economy implementation effect evaluation index, method and the countermeasure of promoting enterprise implementation of circular economy, combined with the typical case of the circular economy demonstration enterprise specific evaluation, it is necessary to build a set of reasonable design, strong operational evaluation system.

In this paper, a comprehensive analysis of the domestic implementation of circular economy development model of industrial enterprises in the development of the situation on the basis of the level of development of the evaluation index system and evaluation methods of economic business cycle has been studied specifically includes: (1) an overview of the basic theories and principles of circular economy on the process of recycling economy development of the sort. Also introduced the theory of target system; and (2) in a lot of reading on the basis of relevant literature to extract the alternative indexes and indexes by carrying out screening and analysis than many overlapping methods, the eventual establishment of a universal evaluation system and using AHP to determine the value of the index weight; (3) Select the steel, coal, electricity and paper industry, the four typical, introduced its cycle of economic development, combined with industry-specific economic characteristics were analyzed cycle indexes in Cape on the basis of appropriate index system according to the different characteristics of the industry to join the corresponding characteristic indexes improve and establish the index system suitable for different industry-specific features and calculated using the analytic hierarchy process right weight value; (4) to Tianjin SDIC power plant as an example, introduces its characteristic cycle of economic development, combined with the power industry evaluation index system of circular economy, the use of fuzzy comprehensive evaluation method to evaluate their level of economic development cycle, the application of the index system is described.

The end of the article to the full text has carried on the induction and the summary, the main research results at the same time, this paper puts forward the study

limitations, and the future development trend of evaluation index system and the comprehensive evaluation as circular economy was prospected.

Key words: Eco-industrial park; Circular economy enterprises; Evaluation index system; Analytic hierarchy process(AHPs); Fuzzy comprehensive evaluation; Tianjin economic technological development area(TEDA); Tianjin SDIC Jinneng electric power co., LTD(Beijiang electric power)

1. Introduction

1.1 Background

1.1.1 The Development of Circular Economy in China

Since the 21st century, with the rapid development of science and technology, the process of industrialization of human society has been further accelerated. However, in addition to the improvement of living standard and quality, environmental pollution, depletion of resources and over-consumption of energy have gradually become factors that restrict society as an important factor of harmonious development, the survival and development of mankind are faced with numerous crises, and the contradiction between economic development and environmental protection has become increasingly acute. In order to effectively balance the relationship between economic and social development and the environment, make more rational use of resources and reduce pollution, the idea of circular economy gradually formed and developed.

Circular economy is a closed-loop material-type economy (Dai Yong, 2006), which can fundamentally solve the contradiction between economic growth and environmental protection in industrial development, improve economic efficiency, reduce resource consumption and reduce environmental pollution, while giving full play to human resource advantages, It is an inevitable choice for a new type of industrialization.

In recent years, due to the scarcity of resources, the energy crisis, the deteriorating ecological environment and the frequent natural disasters, various countries in the world have been actively implementing a series of policies and practices concerning resource conservation, green, low-carbon, and environmental protection. Among these, fruitful practical activities One is to create a large number of eco-industrial parks. Take Chattanooga, a small Tennessee-based city of the United States as an example. Once a heavily-damaged manufacturing center, Chattanooga has become a reality by implementing eco-friendly measures such as zero emissions, waste recycling and waste decontamination with a complete eco-industrial chain and symbiotic network of eco-industrial park (Dai Yong, 2006). In order to achieve the sustainable development of resources, energy, economy, society and ecology, our country also actively explored and practiced eco-industrial parks. From the establishment of Guangxi's first eco-industrial park in Guigang to the present (Dai Yong, 2006), China approved the establishment of 59 national eco-industrial demonstration zones and passed the inspection and acceptance by the Ministry of Environmental Protection of 26.

With the development of China's current stage of national conditions, from the perspective of discipline development, as circular economy is a new interdisciplinary discipline, its disciplinary theory and method system has not yet formed, especially in the circular economy evaluation system to be further studied. At present, the level of the research on circular economy evaluation is mainly divided into enterprise level, park level and urban level. As a basic unit of social and economic development, the implementation of circular economy plays an important role in the implementation of circular economy in the entire region and the country. In order to further promote and promote the development of circular economy, it is necessary to carry out an effective evaluation of the implementation of circular economy. As far as the current researches are concerned, there is a lack of systematic research on the evaluation index system of circular economy in enterprises. In addition, there are many types of enterprises. Although there are some researches on index system of circular economy in different industries, there is a lack of universally applicable Evaluation method. Therefore, it is necessary to construct a set of universal evaluation index system and evaluation method for the development level of circular economy in enterprises, and then combine the production characteristics of different industries and add the characteristic indexes to form the index system applicable to the industry.

1.1.2 The Development of Renewable Energy in China

As the developing of economy and society of China, an increasing number of energy is required; however, an ever-serious contradiction among energy storage, environment protection and economic development has been made worse by the lack of conventional energy and its pollution on the environment.

China is faced with a sequence of rigorous energy problem: first of all is the Energy Security. Second is the Per Capita Resources Shortage. Thirdly is the deterioration of the ecological environment caused by the conventional energy pollution. Fourthly is the Climate Change caused by GHG. As a result, another kind of energy with the availability of its renewability and non-pollution should grow to be an effective and practical choice to guarantee the future development of not only China, but also the world. With the purpose to maintain a sustainable and stable energy supply, to resolve the current resource and environment limitation and to respond to the climate change, the development and utilization of domestic renewable energy resources is not only the important method to resolve the current contradictions of energy supply and demands but also the strategic choice to realize the future energy and environment sustainable development.

The international community has reached a consensus that high renewable energy penetration is a critical part of the efforts to tackle climate change and control temperature rise below 2 degrees. Europe and America have been first in taking the meaningful step of providing blueprints. As the world's largest developing country, largest coal consumer, and largest emitter of greenhouse gases, China is confronted with challenges that are more urgent and arduous as it transforms toward clean, low-carbon energy.

Coal supplied the majority (nearly 66%) of China's total energy consumption in 2012. The second largest source was petroleum and other liquids, accounting for nearly 20% of the country's total energy consumption. Although China has made an effort to diversify its energy supplies, hydroelectric sources (8%), natural gas (5%), nuclear power (nearly 1%), and other renewables (more than 1%) accounted for relatively small shares of China's energy consumption. The Chinese government plans to cap coal use to 62% of total primary energy consumption by 2020 in an effort to reduce heavy air pollution that has afflicted certain areas of the country in recent years. China's National Energy Agency claims that coal use dropped to 64.2% of energy consumption in 2014. The Chinese government set a target to raise on fossil fuel energy consumption to 15% of the energy mix by 2020 and to 20% by 2030 in an effort to ease the country's dependence on coal. In addition, China is currently increasing its use of natural gas to replace some coal and oil as a cleaner burning fossil fuel and plans to use natural gas for 10% of its energy consumption by 2020. Even though absolute coal consumption is expected to increase over the long term as total energy consumption rises, higher energy efficiency and China's goal to increase environmental sustainability are likely to lead to a decrease in coal's share.

As a result of high coal consumption, China is also the world's leading energy related CO_2 emitter, releasing 8,106 million metric tons of CO_2 in 2012. China's government plans to reduce carbon intensity (carbon emissions per unit of GDP) by 17% between 2010 and 2015 and energy intensity (energy use per unit of GDP) by 16% during the same period, according to the country's 12th Five-Year Plan (2011-2015). China also intends to reduce its overall CO_2 emissions by at least 40% between 2005 and 2020. The current climate change plan released at the end of 2014 reinforced China's commitment to reduce carbon emissions mainly in the energy intensive industries and in construction by 2020. Recently, China projected that its carbon emissions would rise by more than one-third from current levels and peak in 2030. These goals assume that China can reduce its reliance on coal and become a more energy efficient economy in the long run.

Taking high renewable energy penetration as the goal and greenhouse gas emissions and air pollutants as basic constraints, it conducts technical and economic evaluation, power system production simulation, social and economic impact evaluation, etc., and based on these optimizes renewable energy deployment pathways under different scenarios as well as puts forward corresponding implementation schemes. Fossil energy for end-use and energy conversion processes will be significantly reduced, totaling no more than 1 billion tons by 2050. Renewable energy will be vigorously developed, accounting for over 60% of the energy consumption and over 85% of the electricity consumption.

In a high renewable energy penetration scenario where over 60% of end-use energy consumption is electricity, the energy system in 2050 is highly efficient, with energy efficiency 90% higher than in 2010. By that time, primary energy consumption is 3.4 billion tons of coal equivalent, and renewable energy accounts for 62%.

(1) Power Installed Capacity and Power Generation

Based on commercialized power generation technology, the share of power generated from non-fossil fuel will be significantly increased. By 2050, the proportion of renewable energy power generation will rise from 46% under reference scenario to over 85% under the high renewable energy penetration scenario. The amount of power generated from non-fossil energy will account for 91% of China's total power generation, and the share of coal-fired power generation will drop from 75% in base year to less than 7% under the high penetration scenario, while meeting the hourly power demands across China. China’s total installed power capacity will reach 7.1 billion kW, including 880 million kW of coal-fired power, 220 million kW of natural gas power, 100 million kW of nuclear power, 550 million kW of hydropower, 2.4 billion kW of wind power, 2.7 billion kW of solar power, 210 million kW of biomass power, 140 million kW of pumped hydro storage power and 160 million kW of chemical energy storage. Wind power and solar power will become China’s backbone energy technologies under the high renewable energy penetration scenario.

China's total power generation will be 15.2 trillion kWh in 2050 under the high renewable energy penetration scenario, including 1038 billion kWh of coal power, 466 billion kWh of natural gas power, 649 billion kWh of nuclear power, 2187 billion kWh of hydropower, 5350 billion kWh of wind power, 4130 billion kWh of solar power and 1100 billion kWh of biomass power. Renewable energy will account for 85.8% of total power generation and non-fossil energy 91%.

(2) Pollutant Emission

Under the high renewable energy penetration scenario, coal consumption will be effectively controlled and the coal consumption peak can be reached by 2020. The consumption peak of fossil energy will be realized by 2025, and thereby reaching the goal of peaking greenhouse gas emissions by 2030 will be assured and most likely to happen as early as by 2025.

China has made the commitment to peak CO_2 emission before 2030. The high penetration scenario will further drive carbon emission to peak earlier in 2025 and at lower value of 9.23 billion tons, and then decline constantly to 3 billion tons by 2050, taking up 20% of the world's total compared to 1/3 in reference scenario. The China's CO_2 emission is shown in Figure 1.1.

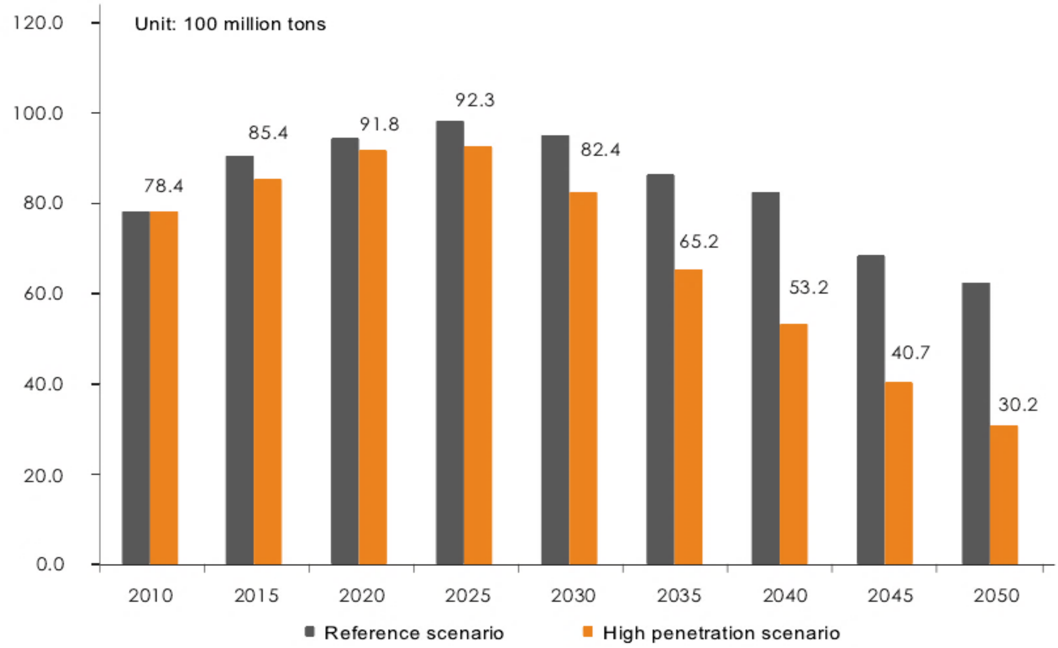

Figure 1.1 China's CO_2 Emission

High renewable energy penetration is expected to replace coal consumption significantly, and by 2050, China's total coal consumption will be less than 600 million tce, only about 1/3 of that as consumed in 2010. Major pollutants and CO_2 emitted by the combustion of fossil energy will decrease significantly. According to the modeling results, China's CO_2 emission will drop from today's about 10 billion tons to 3 billion tons in 2050, a 55% decline from 6.7 billion tons in 2010. In 2050, projected per capita CO_2 emissions will be 2.17 tons, a 51% decline from the world average in 2010 (4.44 tons) and a 46% decline from the world average in 1990 (3.99 tons). The China's CO_2 emission in the global contrast in high penetration scenario is shown in Figure 1.2.

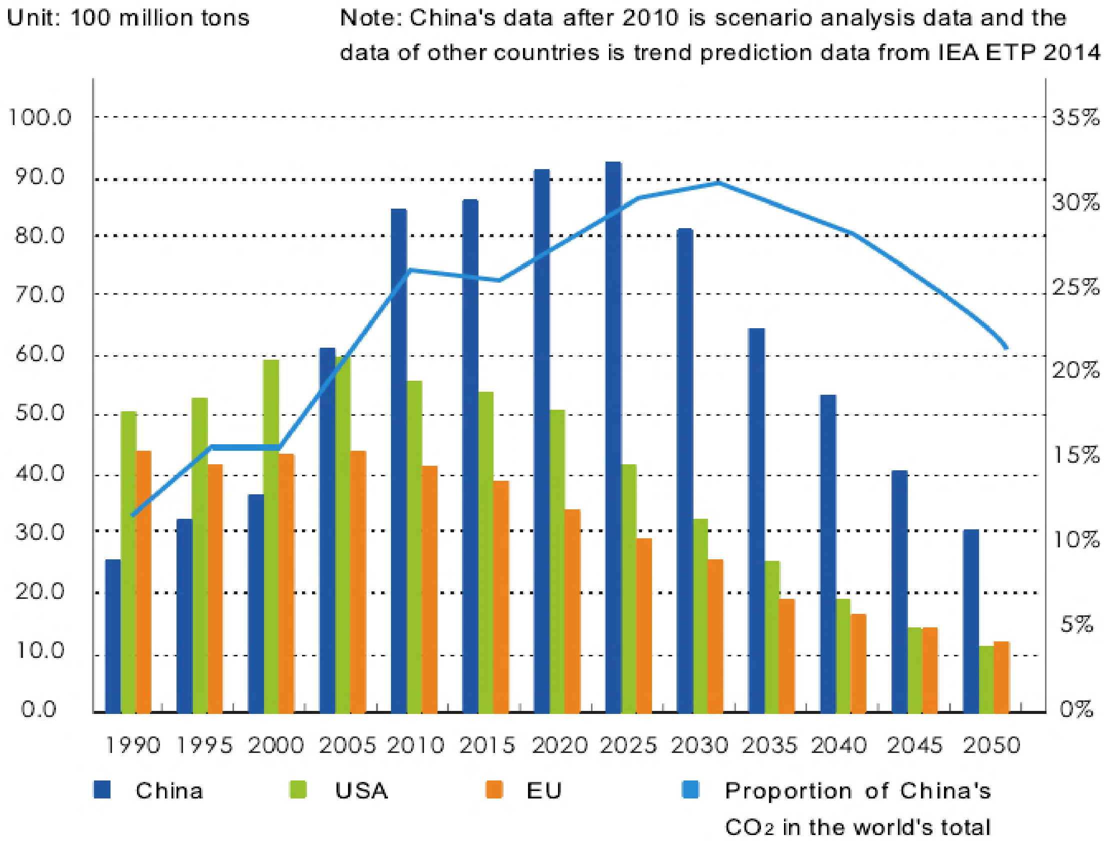

Figure 1.2 China's CO_2 Emission in the Global Contrast

If the entire international community could work together to control the temperature rise to less than 2 degrees Celsius, China's CO_2 emission in 2050 will be only about 1/4 of the world's total. Compared with the share of China's GDP in the world's total, China will make a great difference in improving the world's ecological environment. Europe and the United States have made the industrialization journey with large-scale CO_2 emissions. Other studies predict that Europe and the United States are witnessing the decline of emissions from peak in 2005 to the emission target in 2050. China will reduce its CO_2 emissions in a shorter period by developing high levels of renewable energy that in turn will result in dramatic declines in China's carbon emissions.

China has developed and implemented pollution emission control strategies since the 12th Five-year Plan period. The quantity of SO_2 and NOx emissions of China peaked at 2005 and 2010, respectively, and have since declined year by year. The high renewable energy penetration scenario will further accelerate the reduction in total emissions of major air pollutants, and SO_2 and NOx emissions will be at about 2.5 million tons and 2.7 million tons, respectively. The emission of major pollutants (SO_2, NOx, heavy metal Hg, etc.) will be kept even with 1980 levels. The pollutant emissions in high penetration scenario are shown in Figure 1.3, Figure 1.4.

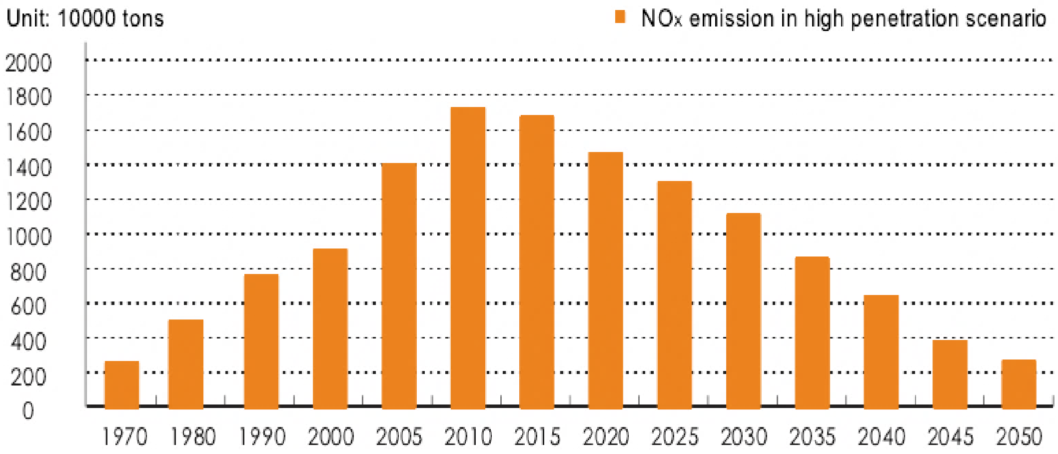

Figure 1.3 China's NOx Emission

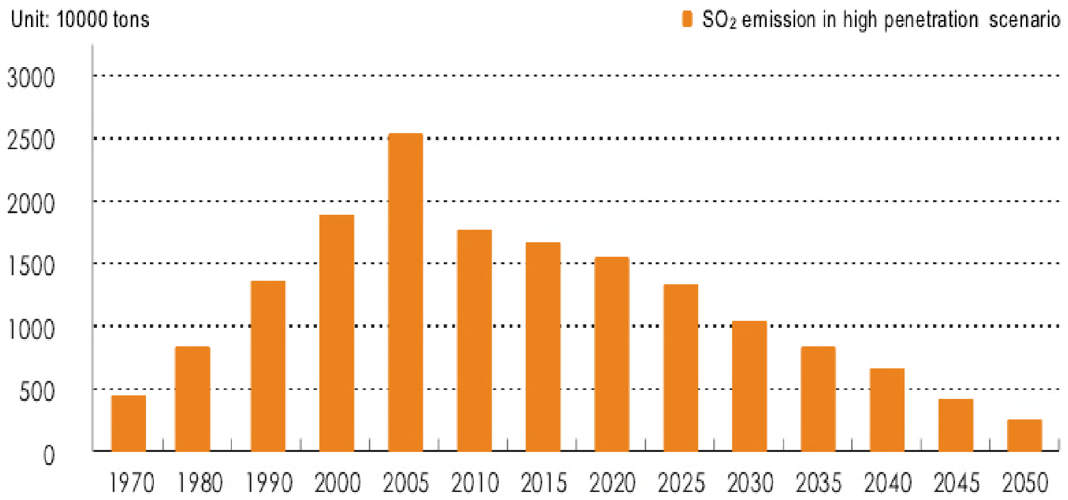

Figure 1.4 China's SO_2 Emission

(3) Development Recommendations

Government departments shall enhance guidance and promotion in terms of strategic planning and policy management from now to future stages; renewable energy industries shall vigorously pursue technological innovations and the development and utilization of renewable energy; the electricity sector shall adapt to the features of new renewable energy technologies and construct a public grid service platform and work on developing a more flexible power system; the building industry, transportation and other end-use sectors shall advocate the replacement of fossil energy by clean electric power and renewable energy, build urban clean energy systems, and develop a smart energy Internet, thereby jointly establishing the future energy system and realizing the energy revolution.

1.2 The Research Significance

It is difficult to accurately evaluate the extent of sustainable development and the level of comprehensive development in both the establishment of eco-industrial parks and the eco-renovation of other parks (Li Guocheng, 2009). Not only lack of suitable quantitative indexes, it is difficult to form a set More mature evaluation index system, and can not choose scientific evaluation methods and models to evaluate their development status, not to further provide guidance and constructive suggestions for the future development of the park. Therefore, it is very important to establish a set of index system that can accurately evaluate the sustainable development level and comprehensive development level of the park and is also practical and operable.

In view of the current situation of China's development, many enterprises are independent of the eco-industrial parks. At present, the research on the circular economy mainly focuses on the national and industrial parks. There are relatively few studies on the circular economy of enterprises and no formation Unified standards and architecture framework (Li Guocheng, 2009). Based on this, this article starts from the six aspects of economic benefits, resource and energy consumption, waste discharge, recycling and other six aspects to establish recycling economy evaluation index system and carry on the weight assignment, at the same time through the relevant models Evaluation, and ultimately achieve the purpose of evaluating the implementation of circular economy enterprises. This is of great significance for the improvement of the theory of circular economy, the guidance of the implementation of circular economy, the field of enterprise appraisal and the direction of development. In addition, taking Tianjin Tianjin Guotou Jinneng Power Generation Co., Ltd. as an example, this paper evaluates the level of circular economy development in the power industry based on the evaluation index system and evaluation model of the circular economy in the power industry, which guides the progress of the evaluation index system effect.

2. Relevant Studies and Research Objectives

2.1 Relevant Studies

2.1.1 Circular Economy Evaluation System

2.1.1.1 Theories and Developments

The idea of circular economy budding can be traced back to the rise of environmental protection in the 60's. In 1962, American ecologist Rachel Carson published Silent Spring, pointing out the dangers that the biological world and mankind are facing. The term "circular economy", first proposed by the U.S. economist K Bolding, mainly refers to the whole process of resource input, enterprise production, product consumption and disposal within the large system of people, natural resources and science and technology, Transforming the traditional linear growth economy, which depends on resource consumption, into an economy that relies on the development of an ecological resource cycle (Wang Zhuojuan, 2006).

After the 1990s, the development of knowledge economy and circular economy become two major trends of the international community(Wang Fuxin, 2005). Since the 1990s, China has introduced the idea of circular economy. Since then, the theory and practice of circular economy continue to deepen. 1998 introduced the concept of circular economy in Germany, establishing the "3R" principle of the central position; 1999 from the perspective of sustainable production of circular economy development model integration; in 2002 from the perspective of the new industrialization of circular economy development significance; 2003 will cycle Economy into the scientific concept of development, the establishment of the development strategy of material reduction; 2004, proposed from different spatial dimensions: the city, regional and national level to develop circular economy (Tang Yan, 2008).

2.1.1.2 The Principles

The development of circular economy should follow the principle of "3R", that is, the principle of "Reduce, Reuse, Recycle".

(1) Reduce, to minimize the investment of resources as the goal. Reduce the use of materials and energy during production and consumption. Starting from the source, saving resources and energy and reducing emissions of pollutants aims to achieve the expected production and consumption goals with less investment in raw materials and energy. For example, we make our products smaller and lighter; making packaging simple and practical rather than luxurious and wasteful; and minimizing waste during production and consumption.

(2) Reuse, with the goal of maximizing waste utilization. Prolong the use of products and services for the length of time, improve the utilization of products and services, require products and packaging can be repeatedly used repeatedly to reduce disposable consumption. Producers in the product design and production, should be discarded one-time use of the pursuit of profit thinking, as far as possible to make the product durable and re-use.

(3) Recycle, with the goal of minimizing pollution emissions. Reuse waste as a resource, create new products with less energy usage, and reduce the amount of final disposal of waste. It is required that the product be reused as an available resource after it is used. It also requires that the scrap, intermediate materials and other materials generated during the production process be returned to the production process or otherwise utilized.

2.1.1.3 The Organizational Hierarchy

From the organizational level of resource flow, circular economy can be developed from three aspects: small cycle at a single enterprise level, medium cycle at industrial park level and large cycle at social level.

(1) At the enterprise level, based on the material circulation within the enterprise, a small cycle within the economic entities such as enterprises and production bases

should be constructed. Rely on scientific and technological progress, give full play to the initiative and creativity of enterprises in order to improve the efficiency of resource and energy use and reduce waste for the purpose of building a micro-recycling economy system.

(2) At the park level, taking the material circulation in the industrial concentration area as the carrier, the mid-cycle between enterprises, industries and production areas will be built. With the promotion and application of eco-parks in a certain geographical area as the main form, through the rational organization of industries, the establishment of inter-firm energy flow, logistics integration and resource recycling in the vertical and horizontal industries, with emphasis on waste exchange, resources Comprehensive utilization of low-emission or even "zero discharge" of pollutants produced in the park to form a circular industrial cluster or a circular economy, to achieve the full utilization of resources between different enterprises and between different industries.

(3) At the social level, focusing on the material cycle of the entire society, a major cycle of society as a whole, including production and daily life, should be constructed to coordinate the development of urban and rural areas and co-ordinate production and life. Through the establishment of a circular economic circle between urban and rural areas and between human society and the natural environment, a material cycle of production and consumption, including production, consumption and recycling, Construct a social system that is in line with circular economy and build a resource-saving and environment-friendly society so as to maximize economic, social and ecological benefits.

2.1.2 The Relevant studies of Circular Economy in Foreign Countries

2.1.2.1 Eco-Industrial Park Development

Eco-industrial park construction first started in Europe. In the 1970s, Denmark established the world's first eco-industrial park, Kalunborg industrial symbiosis

(Figure 2.1). The "Park" with power generation, oil refining, pharmaceutical and gypsum board factory as the core four companies, with a business by-product or waste as raw materials of another business through inter-firm industrial symbiosis and metabolic ecology of the community to establish a "Pulp and paper"," fertilizer-cement", and "steel-fertilizer-cement". Power plants use refinery exhaust gas as a fuel, power plant coal fuel by-products are used to produce cement and paving materials, power plant heat is used to heat fish farms and urban residential buildings, and power plants and refineries share cooling Water (Yuan Zengwei).

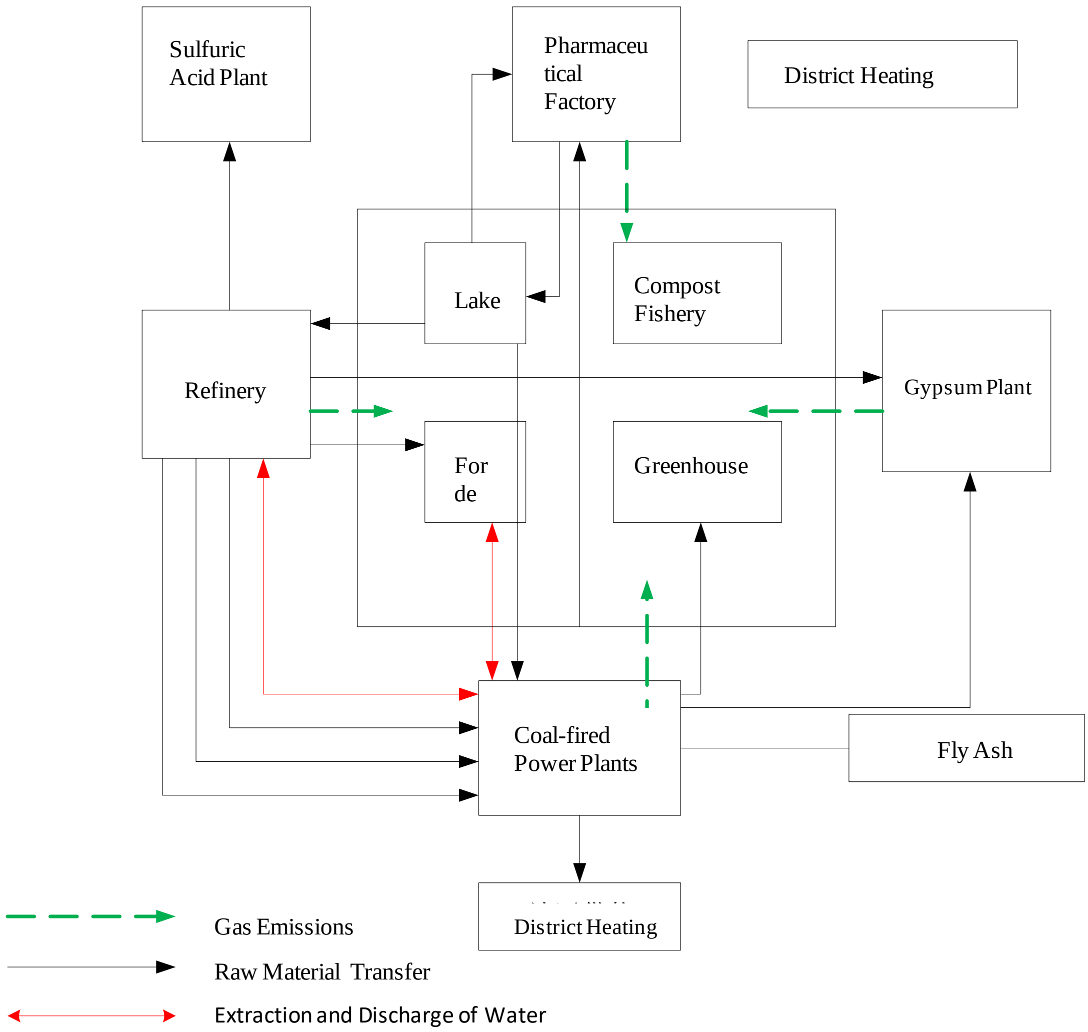

Figure 2.1 Kalundborg "Eco-industrial Park" Schematic

After decades of continuous development, Kalundborg Industrial Park in Denmark has become a model for the world's eco-industrial park (Tian Xiaogang, 2012), and its successful experience has drawn the attention of other countries in the world. Enter the 20th century, 90's, Europe conducted a large-scale eco-industrial park construction, according to a survey report from the United Kingdom: As of 2005, there are a total of 60 eco-industrial park projects in Europe, most of which eco-industrial park in the park Within the formation of a by-product symbiotic network, about 20% of the eco-industrial park using renewable energy recycling technology (Wei hanwu, 2010).

The United States is also one of the most actively engaged in the practice of eco-industrial parks in the world. From the demonstration sites of four eco-industrial parks in 1994 to 1997 and the short span of three years, the United States plans to build 15 eco-industrial parks. The park covers a wide range of environmental industries ranging from bio-energy development, cleaner production to waste treatment and recycling. The US Eco-Industrial Parks are mainly divided into three major categories. The first category is the Eco-Industrial Parks that are reformed, that is, ecological transformation of existing urban or park areas, such as Chattanooga, Tennessee; the second category is the new Of the eco-industrial park, such parks mainly for waste recycling, turning waste into treasure, similar to China's vein industrial park, such as Oklahoma Choctaw; the third is a virtual eco-industrial park, this park by Based on the existing members of the park, new members are recruited. For example, the introduction of thermal power plants and waste solvent recycling plants will play a role of "networking" of industrial ecological networks (Yuan Zengwei). Typical examples are the Brownsville Eco-Industrial Park.

In Asia, Japan was one of the earliest countries to develop eco-industries (Tian Xiaogang, 2012). At present, there are 10 eco-cities and towns projects built, and there are about 30 eco-industrial parks in Asia, ranking the first in Asia. There are Ya-pears in the more influential parks Industrial Park and Fujisawa eco-industrial park (Wei hanwu, 2010).

In addition, many developing countries also actively carry out eco-industrial park to explore practice. Countries such as Thailand, Indonesia, Namibia and South Africa (Tian Xiaogang, 2012 and Wei hanwu, 2010) plan and construct a number of eco-industrial parks with their own characteristics.

2.1.2.2 Enterprises Development

Since 1972, Germany has set up the Waste Disposal Law, the Packaging Regulations, the Circular Economy and the Waste Management Law, etc. since 1972, raising the circular economy system to the legal level and using law Means the implementation of circular economy in industrial enterprises to be restrained. The 1990 Pollution Prevention Law passed by the United States proposed to supplement and replace the pollution control policy based on end-of-pipe treatment with pollution prevention policies. At the same time, the government encouraged the development and utilization of clean energy through financial means, Promote the development of circular economy. Japan is the most comprehensive country in circular economy-related legislation and the country with the most efficient circulation. The promotion and guarantee of a sound legal system have brought the idea of circular economy deep into the hearts of the people and enterprises and the public can respond positively, widely and respected.

For the development of evaluation methods of circular economy in foreign countries, many scholars at home and abroad also have a lot of research. The World Resources Association (WIR) conducted a material flow analysis of the country's economic development and related indexes in the "Weight of the Country" (2000), and compared and analyzed mainly Germany, Austria, the Netherlands, the United States and Japan. The country's output indexes include the domestic hidden material flow, industry indexes, domestic output, loss indexes, the output of domestic production processes, the net increase in stock, and the index of gateways (Tian Xiaogang, 2012). Japan's "Plan to Establish a Recycling Society" proposed three major indexes based on material flow analysis: final disposal volume, recycling rate and resource productivity (Wei hanwu, 2010). The domestic scholar Chen Wenhui learned through the investigation and research on the index system of circular economy abroad that foreign scholars proposed and studied economic welfare indexes, real saving rate (GSI), green GDP, domestic development scale (MDP), ecological footprint (EF), The real progress index (GPI) and other indexes of the data, the economic development and environmental protection construction, residents living happiness combine to study the development of circular economy made an important contribution. Liu Yongxiang and other studies have learned that since the 90s of the 20th century, with the formulation of ISO14031 environmental performance evaluation standards by the International Organization for Standardization, the evaluation of environmental performance and environmental performance of enterprises has also been gradually incorporated into the evaluation of enterprise development.

2.1.3 The Relevant studies of Circular Economy in China

2.1.3.1 Eco-Industrial Park Development

Compared with foreign countries, China's eco-industrial park started late, eco-industrial park planning and construction began in the late 90s of last century.

The development of China's industrial park has gone through roughly three stages (Wei hanwu, 2010): the first stage is Economic and Technological Development Zone, which has low technical content and serious environmental pollution; the second phase is High-tech Industrial Development Zone. High-tech as the support, although the development of the first generation of parks progress, but did not fundamentally change the resource consumption and environmental pollution problems; the third stage for the eco-industrial park, the park and the first two stages of the main difference is : It takes ecological industry theory and circular economy theory as guidance and focuses on the construction of ecological chain and ecological network in the park (Liu Hongci, 2011) in order to maximize the efficiency of resource utilization, reduce pollutant emissions and protect the ecology and environment.

Inspired by the successful experience of foreign eco-industrial parks, China started the pilot project of Eco-Industrial Parks in 1999. With the support of the State Environmental Protection Administration at that time, China's first eco-industrial demonstration park - Guangxi Guigang Eco-Industrial Park , The park takes the sugar cane sugar enterprise as the core and forms the ecological industrial chain around the six systems of sugar cane, sugar refining, paper making, alcohol, combined heat and power, and environmental comprehensive treatment (Liu Hongci, 2011), becoming the largest and most advanced Fast eco-industrial park. In the following few years, various provinces and cities in China successively carried out their own planning and construction of eco-industrial parks and built a large number of eco-industrial parks in China. In 2007, the Ministry of Environmental Protection promulgated and promulgated the policy documents such as Guidelines for the Planning of Ecological Industrial Demonstration Parks (Trial) (2003) and Measures for the Administration of National Ecological Industrial Demonstration Parks (Trial) (2007) To regulate China's eco-industrial park planning, construction and certification (Li Guochen, 2009).

As of January 23, 2014, the number of national eco-industrial demonstration parks approved by the Ministry of Environmental Protection of China reached 59, and a total of 26 were approved by acceptance.

In view of the industrial structure of our country's eco-industrial park, at present, China's eco-industrial park is divided into three categories: comprehensive, industrial and intravenous industries.

In the "Integrated Eco-Industrial Park Standards" (HJ274-2009), "Industrial Eco-Industrial Park Standards" (HJ / T273-2006) and "Venous Ecological Industrial Park Standards" promulgated by the MEP (HJ / T275-2006). Respectively, on the general category, industry and vein industry category 3 eco-industrial park made the following definition.

(1) Comprehensive eco-industrial parks

The integrated eco-industrial park is an industrial park composed of enterprises from different industries. It mainly refers to the eco-industrial park transformed from industrial parks such as high-tech industrial development zones and economic and technological development zones.

(2) Industry Ecology Industrial Parks

Industry Ecology Industrial Park is an eco-industrial park formed by one or several enterprises of a certain type of industrial industry as the core through the integration of material and energy and the establishment of symbiotic relationship among more similar enterprises or related industries and enterprises.

(3) Vein industrial eco-industrial parks

Vein industry (resource recycling industry) is based on the premise of ensuring environmental safety, to save resources and protect the environment for the purpose of using advanced technology, the production and consumption of waste generated during the process into reusable resources and products to achieve Recycling of various types of waste and resource-based industries, including the conversion of waste into renewable resources and the processing of renewable resources into products, are two processes. Intra-venous industrial eco-industrial park is an eco-industrial park mainly constructed by enterprises engaged in the production of vein industry.

At present, China's 59 approved the construction of national eco-industrial demonstration zone, comprehensive park 48, accounting for about 81% of the total; industry-based park 10, accounting for 17% of the total; vein industrial park 1, accounting for about 2% of the total. Its type distribution is shown in Figure 2.2. In the eastern region, 35 (13 in Jiangsu, 6 in Zhejiang, 5 in Shandong, 4 in Guangdong, 3 in Liaoning, 2 in Shanghai, 1 in Fujian and 1 in Tianjin) accounted for 59% of the total. Central China 15 (3 in Hunan, 3 in Jiangxi, 2 in Jilin, 2 in Shanxi, 2 in Henan, 2 in Anhui and 1 in Hubei), accounting for about 26%; 9 in western China (2 in Inner Mongolia, 2 in Guizhou and 2 in Guangxi 1, Yunnan 1, Xinjiang 1, Shaanxi 1, Chongqing 1), accounting for about 15%. Its geographical distribution is shown in Figure 2.3. Among the 26 national eco-industrial demonstration zones that have been approved for acceptance, 24 are general-purpose parks, accounting for 92% of the total; and 2 are industry-type parks, accounting for 8% of the total.

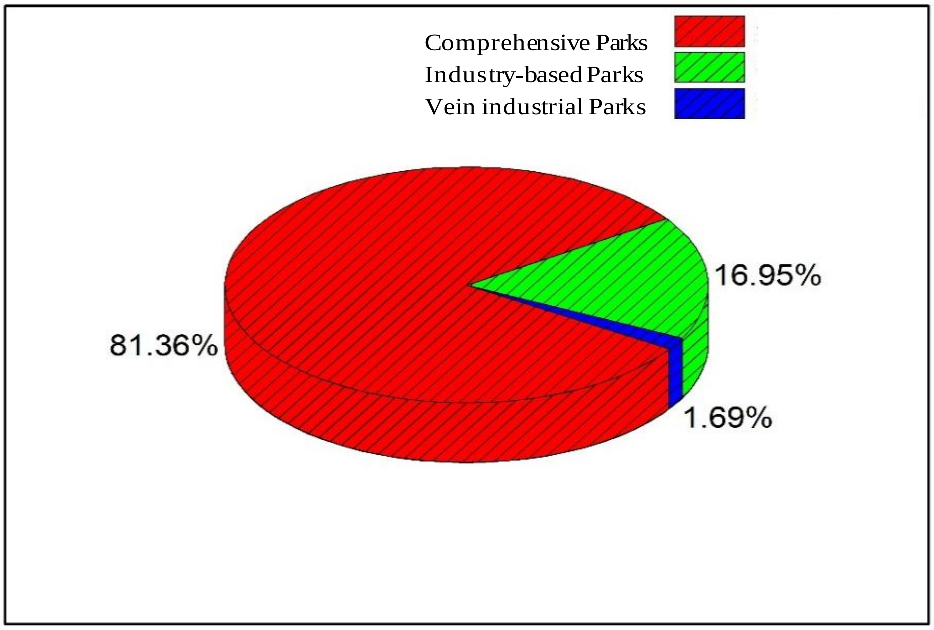

Figure 2.2 National Ecological Industrial Demonstration Zone Type Distribution

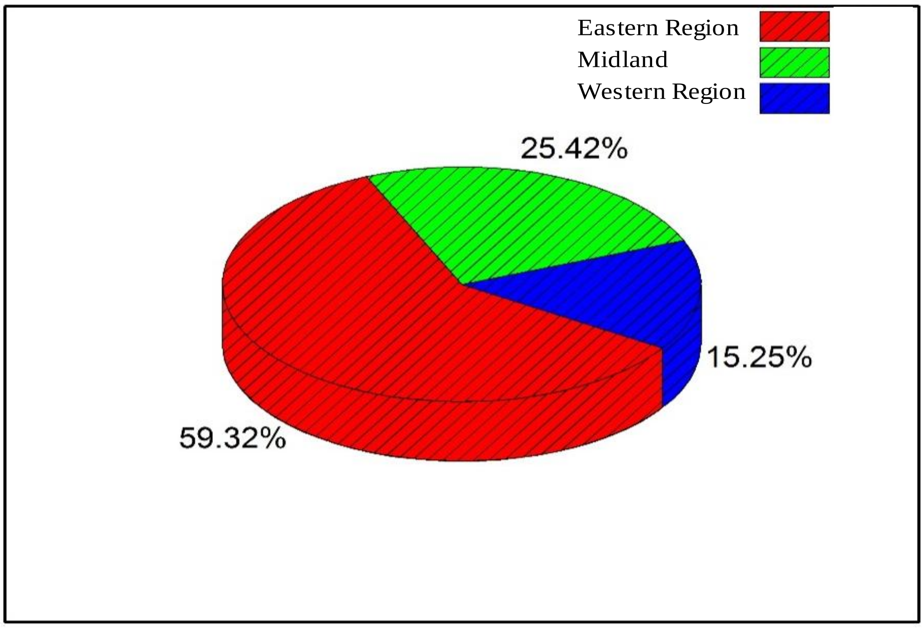

Figure 2.3 National Ecological Industrial Demonstration Zone Geographical Distribution

2.1.3.2 Enterprises Development

In the enterprise, park and regional level on the implementation of circular economy evaluation, in recent years, many scholars have studied. Zhong Taiyang added the index of "trend of resource reduction and utilization" to the evaluation index system of circular economy development, using the ratio of the increase of water consumption, power consumption and energy consumption to the increment of GDP as the evaluation index, and An example of the evaluation of the development level of circular economy in Jiangsu Province is given. Tian Fengquan that the industrial enterprise circular economy index system consists of resource output indexes, resource consumption indexes, comprehensive utilization of resources indexes, waste disposal indexes to reduce the four major components. Guan Weidong from the perspective of circular economy, the enterprise's green competitiveness of the index system for the construction and evaluation, and the use of fuzzy mathematical evaluation and data envelopment analysis of two evaluation model methods, at the same time introduced 16 home manufacturing enterprises evaluation case. The research of Chen Yong aimed at the iron and steel enterprises, first set the evaluation index of circular economy development level of iron and steel enterprises to four first-level indexes, namely the comprehensive utilization efficiency index, the main energy consumption and consumption level indexes, pollution control status indexes, resources Reuse and re-use of these indexes, which basically reflect the reduction, re-use and recycling of circular economy requirements, which are four first-level indexes were expanded to 12 second-level indexes, and further broken down into 66 third-level indexes , The development of circular economy in enterprises conducted a more detailed study and evaluation. Zheng Jiliang for the high energy-consuming industries, including steel, metallurgy, chemical industry, building materials, thermal power and other industries designed the index system structure, combined with a smelting enterprises in Yunnan gives a specific index system. Xu Jun gave the evaluation index system for coal enterprises and introduced the evaluation model method of fuzzy neural network. Finally, taking Hebi Coal Group as a case, the actual data were calculated and analyzed and evaluated. Yang Xiaolongput forward the evaluation index structure for petrochemical enterprises, and carried on the comprehensive evaluation by AHP and fuzzy comprehensive evaluation method. Finally, a case was given to a petrochemical enterprise in Heilongjiang Province. Yu

Xiaozhong of Southwest Petroleum University introduced the evaluation idea, evaluation process and method of 360-degree performance appraisal for petroleum enterprises. Taking a natural gas field in Sichuan as a case, the data were evaluated.

2.1.4 Evaluation Index System

2.1.4.1 Application of Index System in Eco-Industrial Park Circular Economy Evaluation

Zhang Lina(2006) established the evaluation index system based on the analytic hierarchy process with the sustainable development level of eco-industrial park as the evaluation objective. The criteria level includes the level of economic development, the stability of eco-industrial chain, infrastructure construction, ecology Industrial chain flexibility, recycling capacity, environmental protection, emission intensity of pollution, ecological construction, improvement potential of ecological environment, policies and regulations and park management 11 aspects of the evaluation study, and using the index system of Dalian Economic and Technological Development Zone conducted a comprehensive evaluation , The evaluation results show that Dalian Economic and Technological Development Zone, the level of sustainable development as a general.

Huang Kun and Chen Senfa(2004) evaluated the sustainable development level of eco-industrial parks from three aspects: the development level of the park, the development capacity of the park and the coordination degree of the park development. Among them, the development level of the park covered the economic performance, Progress and environmental quality of the three indexes of a total of 12; Park development capabilities, including resource potential, economic growth, environmental sustainability, science and technology education and business environment of a total of 21 indexes of the five; Park Development Coordination includes recycling capacity, environmental governance Strength, economic and social coordination and policy management of a total of four 14 indexes. The index system more comprehensive analysis and evaluation of the park economy, society, resources, environment, management of the five major systems.

Wu Wei and Chen Gongyu et al. (2002) established a comprehensive evaluation index system of eco-industrial system based on the degree of system development, system development sustainability and system development coordination as the target level from the perspective of systematic study. : The system development level takes into account 21 indexes in terms of social progress, economic performance and environmental quality. The sustainability of the system takes into account 12 aspects of the social development sustainability, the economic development sustainability and the environmental sustainability the index of system development takes into account 15 indexes in four aspects: social and economic coordination, economic and environmental coordination, environmental and social coordination and policy and management.

Chen Xilian(2007) adopted the structure-coordination-function framework model, taking the comprehensive evaluation index of eco-industrial park as the general objective, taking into account the structure of the industrial park (including the structure of the eco-industrial chain network, the structure of the infrastructure, the community structure, System structure, staffing structure, management structure and investment structure), coordination (including parks and natural environments, parks and communities and parks) and functions (value appreciation, material circulation, energy flow and information flow) The new concept point of view provides a good reference value and reference for the further study of eco-industrial park.

2.1.4.2 Application of Index System in Enterprise Circular Economy Evaluation

Hu Ying (2005) improved the comprehensive evaluation system of the steel industry and introduced the "Green Index" to establish a "green comprehensive evaluation system" for the steel industry. The comprehensive evaluation index consists of the efficiency index and the green index, of which the weight of the effectiveness index accounts for 70 %, Including the total asset contribution rate, asset-liability ratio and other financial indicators; green index weight accounted for 30%, including the comprehensive energy consumption per ton of steel, gas recovery and utilization, industrial wastewater discharge compliance rate of 9 indicators.

According to Li Zhijuan (2006), a comprehensive evaluation index system for circular economy enterprises is constructed based on economic benefits, logistics energy flow and social environment. She thinks that for the performance evaluation of circular economy, not only the business performance of the enterprises should be considered, but also the social and environmental factors and other factors. In the selection of evaluation methods, she uses the uniform approximation method to evaluate the development of circular economy enterprises.

Yang Huafeng (2006) discussed the principle and path of evaluation index system of circular economy in order to promote the development of recycling economy and promote the competitiveness of enterprises. The paper also established the principles and paths of evaluation index system of circular economy and built up the competitiveness of resources, technology, management and economic competitiveness , Environmental competitiveness and responsibility competitiveness as the core of circular economy based on the competitiveness of enterprises evaluation index system.

Ouyang Chunhua (2008) put the concept of circular economy into the independent innovation of enterprises and built the evaluation index system of enterprise independent innovation based on circular economy. For the composition of the index system, she thinks that it includes the independent innovation input index, the independent innovation output capacity Indicators, self-innovation activities, capacity indicators and independent innovation resources utilization capacity indicators in four areas.

2.2 Research Objectives

Based on the comparison of several theories and methods for building circular economy evaluation index system, there are many shortages described in Chapter 2.1: i) there is not an index system that can comprehensively evaluate the circular economy, and the selection of the evaluation index is not comprehensive enough; ii) there are three levels of evaluation of circular economy (urban, industrial park and enterprise), but existing research is only at one level; iii) there is not a comprehensive evaluation model for circular economy, and the existing research evaluation method is simple and single.

In this paper, a great deal of literature has been reviewed for the circular economy development. A circular economy evaluation index system of eco-industrial parks and enterprises was built, and the circular economy comprehensive evaluation model of eco-industrial parks and enterprises were improved.

1) What's new in this study?

i) Unified considering the establishment of evaluation index system from six aspects(economic, resource utilization, environmental protection, eco-friendly, management and social);

ii) Selected the circular economy evaluation indexes as comprehensively as possible, 89 primary indexes of eco-industrial parks and 47 primary indexes of enterprise were selected to circular economy evaluation index system. After screening and analysis of the primary indexes, unnecessary indexes were removed, and the indexes that 50 remain indexes of eco-industrial parks and 34 remain indexes of enterprise were established to construct the comprehensive evaluation index system.

2) What's different from simple AHP in this study?

iii) this study analyzed the two levels circular economy of industrial parks and enterprises, in addition, the characteristic indexes were selected separately because of the characteristics of different industries, and then four special industries are analyzed;

iv) established the multiple comprehensive evaluation model of circular economy, the application of AHP+Multi-Level extension synthesis evaluation method(MESE) in parks level, and the application of AHP+Fuzzy comprehensive method in enterprises level;

3) Why do new methods in this study?

v) An eco-industrial park (TEDA) and an enterprise (Tianjin SDIC power plant) as the example, their circular economy levels were conducted respectively the comprehensive evaluation according to established evaluation index systems.

2.2.1 Research Contents

In this paper, a great deal of literature has been collected and reviewed for the development of eco-industrial parks both at home and abroad (Li Xiaopeng, 2008). Based on the comparison of several theories and methods for building eco-industrial park evaluation index system, Industrial park evaluation index system and its evaluation model and other issues were studied.

In addition, in view of the research on the index system and evaluation method of industrial enterprises in the implementation of circular economy development mode in China, from the aspects of economic benefits, resource and energy utilization, waste discharge, recycling, business management and social benefits, The set is suitable for evaluating the implementation of circular economy enterprise universal index system, and through the determination of index weight and related evaluation methods of screening and evaluation model to establish the evaluation system, and then according to the characteristics of different industries to join the corresponding characteristics Indexes to improve, establish suitable for different industry-specific characteristics of the index system. Finally, the evaluation index system and evaluation methods are applied to the comprehensive evaluation of the study. Finally, it will guide the implementation of circular economy, perfect the theory of circular economy, and expand the role of the direction and field of enterprise evaluation.

(1) Introduction

The research background and significance of the topic selection are expounded. The current development of the eco-industrial parks at China and abroad are introduced. At the same time, the research methods, contents and overall ideas are briefly introduced.

(2) Recycling economy and evaluation of relevant theoretical methods

To summarize the basic theory and principle of circular economy, to sorter out the development of circular economy. At the same time, it introduces the related theory of index system method, which lays the foundation for the main body of this paper, the index system of circular economy evaluation.

(3) Eco-industrial park comprehensive evaluation index system and enterprise evaluation index system construction

This paper introduces the design principles, construction procedure and frame structure of the evaluation index system, extracts optional indexes on the basis of reading a large amount of relevant documents, and conducts index screening and overlap analysis by comparative method, expert consultation method and questionnaire survey method, In the end, a universal evaluation index system is established and the meaning and calculation method of each evaluation index are described. Afterwards, AHP is used to determine the weight of the index, and fuzzy comprehensive evaluation method is introduced.

(4) Construction of eco-industrial parks and industry-specific comprehensive evaluation index system

First of all, it introduces the basis and method of evaluation criteria and weight determination; secondly, introduces several kinds of comprehensive evaluation methods to be selected; finally, selects and determines the multi-level extension comprehensive evaluation method to build the system of coordinated eco-industrial park development degree and overall level of development model.

The four typical industries of steel, coal, electric power and paper making are respectively introduced to the development process of circular economy and the characteristics of circular economy are analyzed according to the characteristics of the industry. Based on the universal index system, according to the characteristics of different industries, the characteristic indexes to improve, establish suitable for different industry-specific characteristics of the index system and the use of analytic hierarchy process to calculate the weight value.

(5) Case study

TEDA eco-industrial park is evaluated with the multi-level extension comprehensive evaluation model constructed, and the evaluation results are analyzed, and the improved strategies and measures are put forward.

Taking Tianjin SDIC Tianjin Beijiang Power Plant as a case, this paper introduces the characteristics of its circular economy development. Combined with the evaluation index system of circular economy in the power industry, this paper evaluates the level of its circular economy by using the fuzzy comprehensive evaluation method and applies the index system be explained.

(6) Conclusion and Outlook

At the same time, the paper puts forward the limitations of the research, and prospects the future research trends of index system and evaluation of Eco-Industrial Park.

2.2.2 Research Methods

The scientific research methods used are: expert consultation, data collection, correlation analysis, and analytic hierarchy process, flow analysis, actual measurement, comparative analysis, questionnaire survey, comprehensive evaluation of extension, comparative analysis, case study and so on.

Take the technical route shown in Figure 2.4.

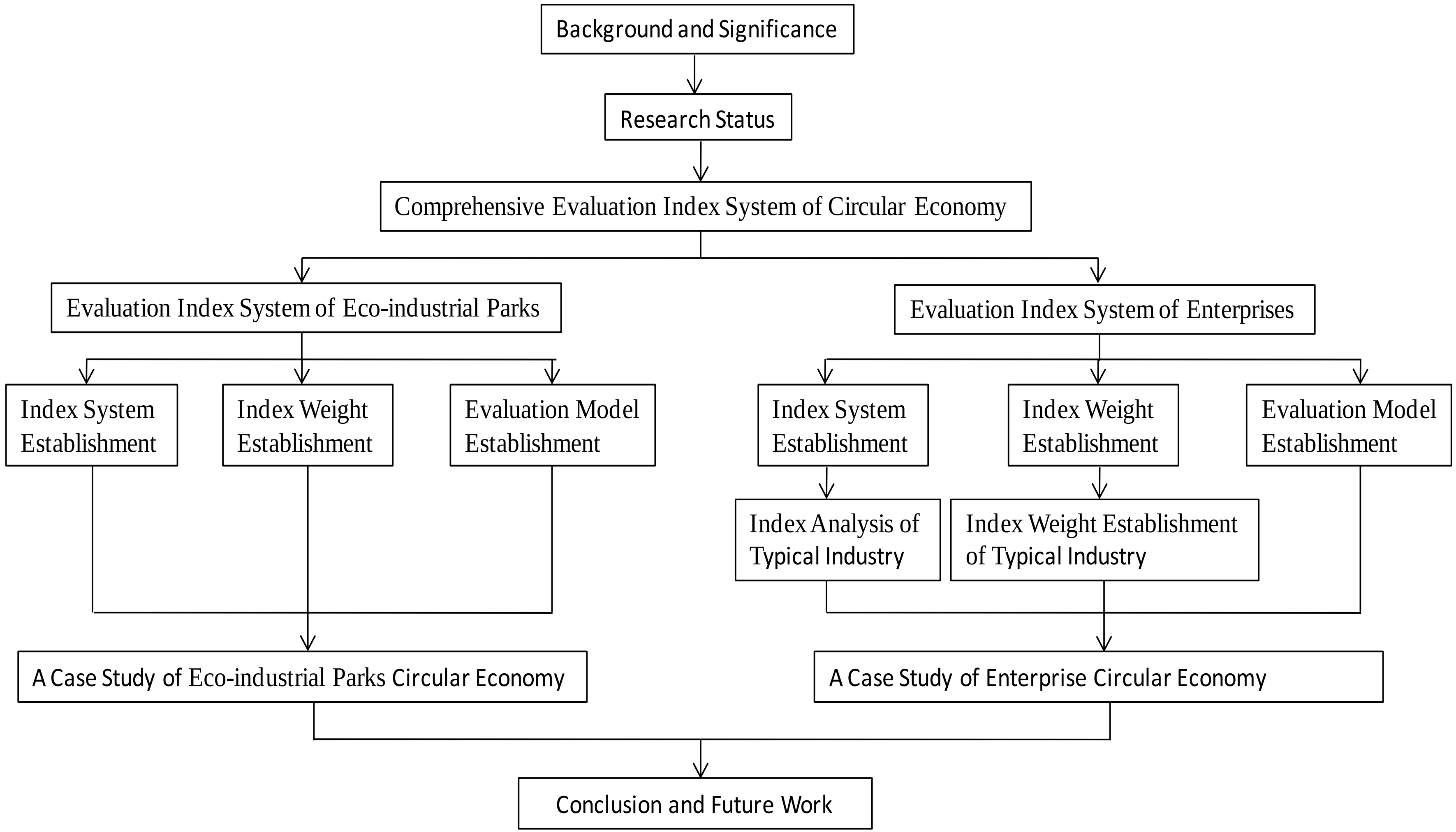

Figure 2.4 The Technology Roadmap of This Study

2.2.2.1 Introduction of Index System Method

(1) The Design Principle

Scientific and rational index system is the basis and guarantee of using index system to evaluate. Therefore, on the basis of following the "3R" principle of circular economy, the design of index system for evaluating the implementation of circular economy in enterprises must also adhere to the scientific, hierarchical and Operability and other principles (Zhu Li, 2011). Specific follow the principle is as follows:

1) Scientific and practical

The design of circular economy evaluation index system should fully reflect and embody the connotation of circular economy and systematically and accurately understand and grasp the essence of circular economy from a scientific point of view(Zhang Lina, 2006). Evaluation index system should be able to reflect the main features of things, data sources should be accurate, scientific approach to deal with specific indexes can reflect the realization of the main objectives of circular economy. At the same time, the index in the index system must be clear and accurate, not ambiguous and ambiguous(Huang Pi, 2004). At the same time, the calculation methods and models used must also be scientifically regulated in order to ensure the truth and objectivity of the evaluation results.

2) Systematic and hierarchical

The development of recycling economy is a complex systematic project, evaluation index system must be able to fully reflect the development of circular economy in all its aspects, with a high level, covering a wide range of systematic features(Wu Wei, 2002). The evaluation index system of circular economy is a complicated system, which includes several subsystems. Different indexes should be adopted at different levels, which are conducive to the government policymakers regulating social and economic development at different levels and allocating resources effectively, To optimize the environment(Chen Xilian, 2007).

3) Dynamic and stability

The index content in the evaluation index system should be relatively stable within a certain period of time, so that the process of circular economy development can be compared and analyzed and its development trend can be predicted. Of course, an absolutely unchanged index system is impossible, and the index system will change over time and with changes in circumstances. The development of circular economy is a gradual process, so the design of the index system should take full account of the dynamic changes in the system can comprehensively reflect the development process and development trends, to facilitate the prediction and management(Tong Li, 2003).

4) Testability and comparability

Evaluation index system should take full account of the availability of data and indexes of the ease of quantification, quantitative and qualitative combination. The evaluation index system of circular economy should be quantified as much as possible (Li Min, 2007). For some difficult to quantify, but its impact on the significance of indexes, you can also use qualitative indexes to describe. Qualitative indexes should have a certain amount of quantitative means corresponding to them, such as the use of expert questionnaires and other means to determine some of the difficult to quantify indexes. In addition, the calculation of indexes should be clear, not too complicated, and the data required for the calculation should be relatively easy to obtain and reliable(Wu Jie, 2009).

5) Completeness and conciseness

Circular economy evaluation index system requires a wide coverage, can comprehensively and comprehensively reflect all aspects of circular economy development. The index system should be relatively complete, that is, the index system as a whole should be able to basically reflect the main aspects or main features of the development of circular economy(Xie Lianke, 2007). However, the subdivision of indexes is inevitable, and it is inevitable that there will be an overlap of indexes and indexes, or even the opposite of each other. This, on the contrary, brings inconvenience to the comprehensive analysis and appraisal. Therefore, the index system needs content that is simple, accurate, and representative. In the index system, the number of indexes should not be too large. In a relatively complete situation, the number of indexes should be compressed as much as possible for easy analysis and calculation (Yan Bohua, 2007).

(2) Building Procedures

The establishment of circular economy evaluation index system is a policy, technical and technical work is very strong, both to ensure that the index is scientific and reasonable, complete and comprehensive, but also reflect the economic usefulness and purpose. Therefore, the number of indexes should be moderate, realistic and acceptable to managers. This needs to be built on a wealth of theoretical knowledge and sufficient practical experience, but also in accordance with certain scientific procedures, the use of scientific methods(Shao Lizhou, 2008). The establishment of the general procedure as shown in Figure 2.5.

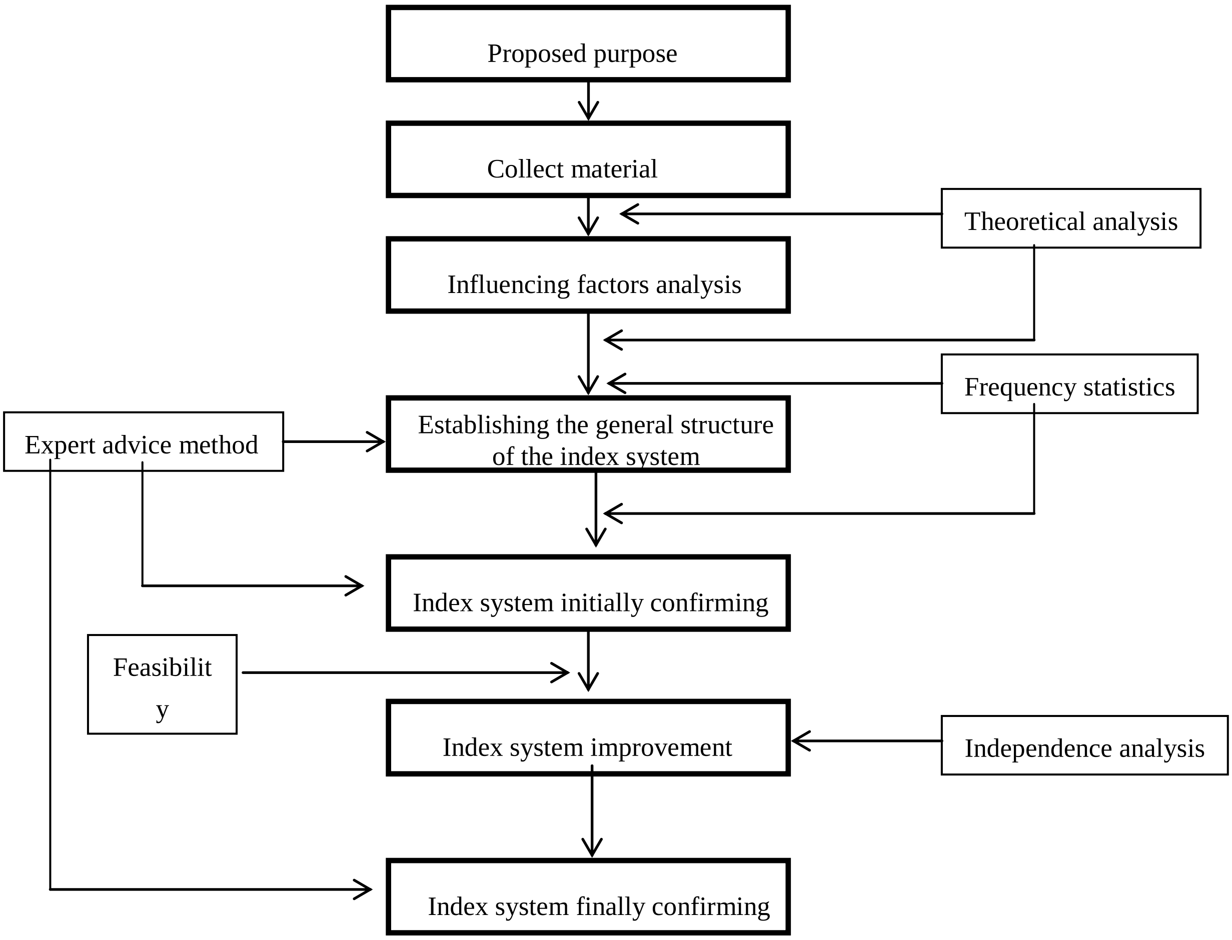

Figure 2.5 Index System to Establish the General Procedure

2.2.2.2 Evaluation Index Screening

(1) Screening Principle

The ultimate goal of establishing a circular economy index system is to guide, monitor and promote the ecological development of parks and enterprises. Therefore, each index should be observable, quantifiable and well-defined. However, in the application process, not the index number is better, the key is whether the selected index reflects the nature of the research object. Therefore, we must make some choices according to the relationship between the index content and the evaluation target, Relevant small or ambiguous indexes, to avoid too many indexes due to factors that lead to expert judgment errors(Zhu Li, 2001).

Therefore, the principles followed by index screening include the following five aspects.

1) The principle of independence

The selected indexes should be of a typical representation, with the indexes avoiding overlapping of information(Zhu Li, 2001). The indexes in the same state should be as independent as possible and the indexes should be as small as possible.

2) The principle of necessity

The selected indexes must closely surround the overall objective of evaluation. Each of the indexes below can reflect the relevant characteristics of the previous index and have irreplaceable characteristics. Indexes that are not relevant to the evaluation content can not be selected.

3) The principle of operability

The acquisition of indexes should be realistic, that is, it can be obtained by referring to the statistical yearbook, statistical data of the parks, the planning report of the park, the report of the development of the park, on-site investigation and evidence collection and expert consultation, and is preferably easy to quantify.

4) The principle of comparability

The indexes selected should adopt international and domestic common names and calculation methods as far as possible so as to be comparable with similar indexes formulated by other countries or organizations. The statistical units of the same kind of indexes should have the same meaning(Ye Chunying,2006), taking into account Indexes of the content of its historical data and current data and the comparability of the data during the planning period.

5) The principle of pertinence

The selected indexes should be targeted at the object and content of the study, the expression of information is accurate and targeted, to discard those who express a wide range of information, the target is not strong indexes(Zhu Li, 2001).

At the same time, the selected indexes should meet the following two basic requirements.

① The number of sub-goals under the same goal should not exceed 9(Zhu Li, 2001);

② Indexes clearly defined, easily understood and accepted.

(2) The Method of Screening

The primary index must go through a screening method, eliminate unsuitable index, reduce redundancy phenomenon. The main method includes two steps: first, after overlaps analysis indexes, to determine which indexes have independence or overlaps(Zhu Li, 2001), secondly, in accordance with the principles of index screening to remove inappropriate index. Specific methods are as follows:

1) The overlap between the index analysis

Index of the overlaps between refers to the index of correlation, the correlation coefficient is higher, the higher the degree of overlap between the indexes, if there is no such relationship between indexes or its minimal correlation coefficient, is called the index of independence. The specific method is as follows:

① the relationship between index assignment

The relationships between indexes are independent, equal and overlap and contain and contained relationship. This paper rules(Zhu Li, 2001): independent relationship is 0, equal relationship is 1, content or information overlap relationship is 2, included or included relationship is 3.

② the relationship between indexes listed matrix

Subordinate relations according to the index of the first logic, based on rule layer index will index system is divided into several sub modules, respectively for each criterion layer (rule layer) index, through theoretical analysis and combining with the consulting experts and give all the indexes of the relationship between the values, and list the relationship Table, as shown in Table 2.1.

Table 2.1 Indexes Interrelation

	M_1	M_2	M_3	…	M_n
M_1	1				
M_2		1			
M_3			1		
…				1	
M_n					1
$\sum$					

Ml-Mn represent the index system variable layer of the indexes. The index is equal to itself, so the diagonal position in the table is 1, the relationship between each index and other indexes by overlapping analysis, the relationship between the values are filled in the corresponding position(Zhu Li, 2001).

2) The selection of indexes

Independent and overlap indexes, the non-compliance indexes were removed for achieving the purpose of streamlining indexes.

2.2.2.3 Method of Determining Weight of Index System

The weight coefficient, also known as weight, is the degree to which the index contributes to the overall objective, reflects the degree of importance attached by the policy maker to the index, and indicates the extent and reliability of the attribute value of the index. In this paper, the analytic hierarchy process to determine the weight of the index system.

(1) The Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a multi-objective decision analysis method. proposed by T.L. Satty et al. who is a famous American operation research scientist in the 1970s. This method is generally used to deal with complex technical, economic and social issues. It stratifies and quantifies people's thinking process, and uses mathematics to provide a quantitative basis for analysis, decision-making, forecasting or control. This method is especially suitable for people's judgment of direction plays an important role in the decision-making difficult to direct and accurate measurement of the situation (Du Dong, 2005). Figure 2.6 is the general steps of AHP.

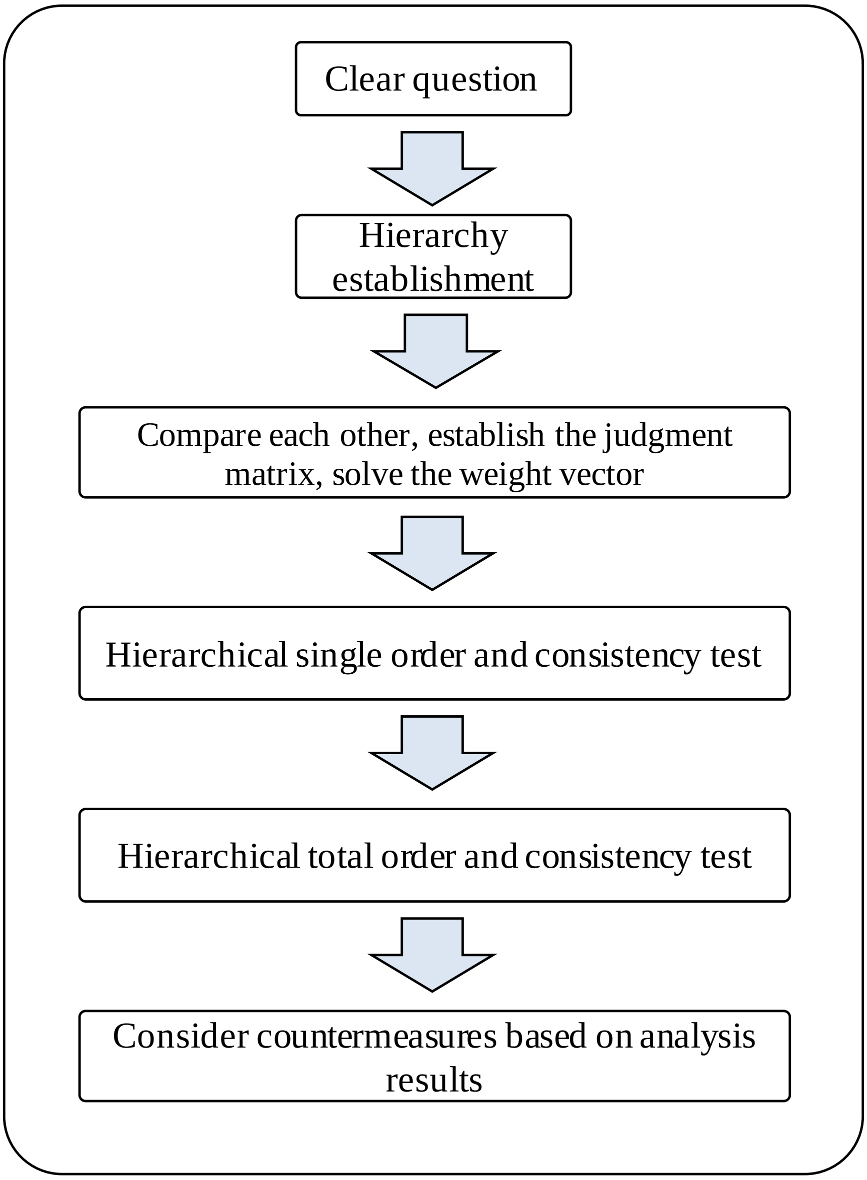

Figure 2.6 AHP General Steps

(2) The Weight Setting of Index System

1) Construction of Judgment Matrix

The indexes are compared with each other to obtain indexes value based on a certain index of the above layer as the judgment criterion. Take the A layer indexes as an example, to compare the importance of A1, A2,..., A5, Ai:Aj=aij, MA=(aij)5×5, as shown in Table 2.2.

In this paper, 1 ~ 9 scale method is used to measure the importance of individual indexes. We give each expert a weighted questionnaire, and then all experts calculate the weight coefficient of each performance index statistically to get the judgment matrix. Proportional scale values and their meanings are shown in Table 2.3(Zhan Yelin, 2007).

Table 2.2 Judgment Matrix M_A

A	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**
A_1	a_{11}	a_{21}	a_{31}	a_{41}	a_{51}
A_2	a_{12}	a_{22}	a_{32}	a_{42}	a_{52}
A_3	a_{13}	a_{23}	a_{33}	a_{43}	a_{53}
A_4	a_{14}	a_{24}	a_{34}	a_{44}	a_{54}
A_5	a_{15}	a_{25}	a_{35}	a_{45}	a_{55}

Table 2.3 Scale Table from 1 to 9

Scale	**Meaning**
1	No.i factor is equally important as No.j factor
3	No.i factor is slightly important than No.j factor
5	No.i factor is significantly important than No.j factor
7	No.i factor is particularly important than No.j factor
9	No.i factor is ectremely important than No.j factor
2，4，6，8	The importance between No.i factor and No.j factor goes between the above the adjacent hierarchies

$a_{ij} > 0$, $a_{ij} = 1/a_{ji}$, ($i \neq j$) and $a_{ii}=1(i,j=1,2,\ldots,n)$)

2) Consistency Test and Hierarchy Single Sorting

Judgment matrix consistency refers to the consistency between judgments in judging the importance of indexes to ensure that no contradictory results appear. However, in actual evaluation of various indexes, subjective bias may often occur due to the complexity of objective things and people's cognition, which makes the possibility of judging inconsistencies. Therefore, we need to be generally consistent in the establishment of the judgment matrix. Therefore, in order to ensure AHP's accurate evaluation and analysis of projects and projects, we need to test the consistency of judgment matrix (He Wei, 2006).

For the matrix A, its characteristic root $\lambda_{max}=n$ and all the other characteristic roots are zero when the matrix is completely consistent. When the matrix A is not completely consistent, then $\lambda_{max}> n$. However, in practice, judgment matrix often can not guarantee complete consistency. Therefore, we refer to the negative average of the other eigenvalues except the largest eigenvalue of the judgment matrix in the analytic hierarchy process as an index of deviation from the consistency matrix, which is:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

In addition, the consistency of the judgment matrix is random, this random consistency index is shown as *RI*, the value of *RI* is related to the number of evaluation indexes n (Zhan, Y.L., 2007), the value of *RI* shown in Table 2.4. The relative consistency index *CR* is:$CR = CI/RI$. When *CR*<0.10, the judgment matrix is consistency, otherwise, it is necessary to adjust the judgment matrix until it is consistency. (Du *et al.*,2005)

Table 2.4 The Value of *RI*

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The calculation steps of the largest eigenvalue:

(1) Calculate the product M_i of each row element of the judgment matrix

$$M_i = \prod_{j=1}^{n} a_{ij}, i = 1,2,3,\cdots, n$$

(2) Calculate the n^{th} power root $\overline{W}$ of M_i

$$\overline{W_i} = \sqrt[n]{M_i}$$

(3) The normalization of $\overline{W} = [\overline{W_1}, \overline{W_2}, \cdots, \overline{W_n}]^T$

$$W_i = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_j}}$$

then

$W = [W_1, W_2, \cdots, W_n]^T$ is the eigenvector.

(4) calculate the largest eigenvalue λ_{max}

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

$(AW)_i$ is The i^{th} element of vector AW.

2.2.2.4 Comprehensive Evaluation Methods of Circular Economy

Evaluation index system with the corresponding evaluation methods can better carry out the status quo on the circular economy and evaluation of the development trend. The existing comprehensive evaluation methods include fuzzy comprehensive evaluation method, analytic hierarchy process, multi-level extension comprehensive evaluation method and gray relational clustering evaluation method.

(1) Fuzzy Comprehensive Evaluation Method

Fuzzy comprehensive evaluation is based on some concepts of fuzzy mathematics to provide some evaluation methods for practical comprehensive evaluation problems. Specifically, fuzzy comprehensive evaluation is based on the application of fuzzy mathematics, applying the principle of fuzzy relationship synthesis, some of the boundaries are not clear, not quantitative factors, from a number of factors to be assessed the degree of membership status of a comprehensive a method of evaluation. Figure 2.7 is the basic step of fuzzy comprehensive evaluation method (Du Dong, 2005).

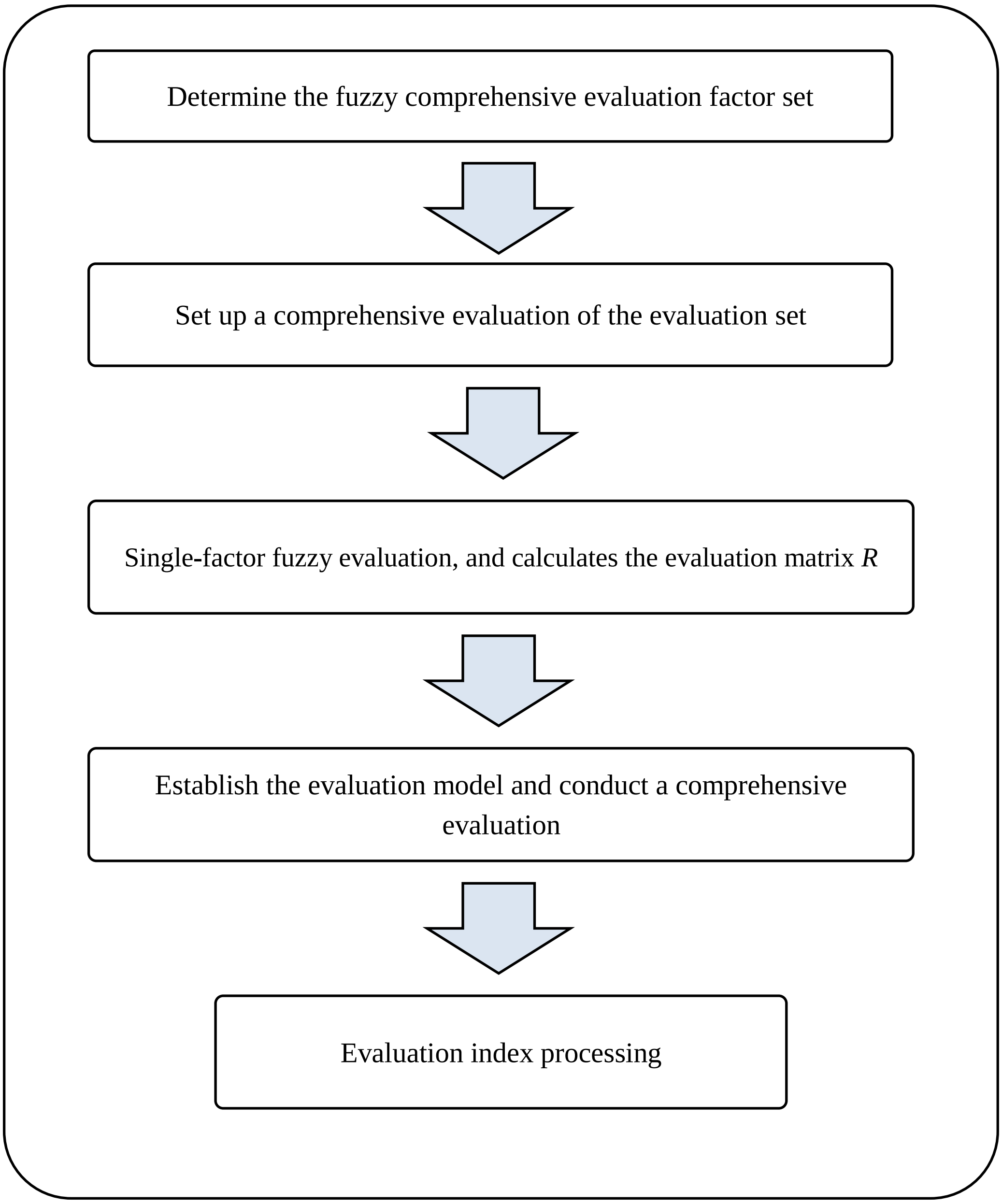

Figure 2.7 Fuzzy Comprehensive Evaluation Steps

1) Determining the set of evaluation factors

Evaluation factors can be defined according to the objectives of the evaluation process. A set of k evaluation factors can be represented as a vector $U=(U_1,U_2,\dots,U_k)$, and $U_i \cap U_j=\emptyset$(i,j=1,2,...,k;i≠j). U_i and U_j are indexes of criterion layer in index system. For each of the U_k, the establishment of its sub-goal factor set: $U_k=(U_{k1},U_{k2},...,U_{kn})$,they are indexes of index level.

2) Determining the set of appraisal grades

The appraisal set can be represented as a vector $V = \{V_1, V_2, \ldots, V_m\}$, in which m represents the number of levels in the appraisal. For example, if m=4, the appraisal vector can be represented as V={excellent, good, fair, poor}.

3) Setting the fuzzy mapping matrix

A group of broadly representative experts(10) are selected to compose of the expert evaluation team. After the experts' fuzzy evaluation on indexes of the above-mentioned four factors, the result is as follows.

As far as economic benefits is concerned, 5 of the experts think it excellent, 4 think it good, 1 think it fail, 0 thinks it poor. Then the subordination of the level of comments on the factor of sales revenue growth rate influencing economic benefits: 0.5, 0.4, 0.1, 0. It can also be written in fuzzy vector R_1=(0.5, 0.4, 0.1, 0).

In general, the fuzzy appraisal matrix of all n factors can be derived and represented as a matrix R, such that if there are n factors and m levels of appraisal grades(Han, W., 2009):

$$R = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{bmatrix} \quad (i=1,2,\ldots,k)$$

In the above matrix notation for R, each row represents the set of appraisal membership degrees to the corresponding appraisal vector V for each evaluation factor U_i in the evaluation vector U.

4) Determining the weight of each evaluation factor

To obtain a comprehensive usability evaluation, the relative importance of each evaluation factor on the overall grading should be quantified. The weight vector can be represented by A(A=(a_1,a_2,...,a_k) and A_k=(a_{k1},a_{k2},...,a_{kn})), which can be formulated by the AHP method, as described in section 2.2.2.3.

5) Getting the overall evaluation result

The overall evaluation result can be obtained by taking into the account the relative weights of each evaluation factor, such that a single vector with the same level of appraisal grades m can be represented by:

$$B_i = A_i \circ R_i = (b_{i1}, b_{i2}, b_{i3}, b_{i4}), (i = 1,2,\cdots,k)$$

$$R = [B_1 B_2 \ \cdots \ B_k]^T$$

$$B = A_i \circ R_i = A_i \circ [B_1 B_2 \ \cdots \ B_k]^T = (b_1, b_2, b_3, b_4)$$

Where "o" is a composition operator, b_m could be operated by a number of possible models. In this study, we assume that all evaluation factors should be considered, such that no single factor is significantly selected or ignored more than others. We therefore choose to use the weighted average-type fuzzy composition operator (M(▪, ⊕)model) that calculates each element b_m of the final appraisal vector by the following formula (Zhou *et al.*, 2017), which is suitable for evaluations in which all weights of factors must be accommodated:

$$b_m = min\left\{1, \sum_{k=i=1}^{n} W_i r_{im}\right\}, (m = 1,2,\dots,n)$$

b_i is the degree to which the evaluation object has the comment V_j. When $\sum b_{ij} \neq 1$, it should be normalized.

6) The validity test of the maximum membership principle

In the fuzzy comprehensive evaluation, for the comment set $V = \{V_1, V_2, \dots, V_m\}$, and $\sum_{i=1}^{n} b_i = 1$. A index for judging the validity of the maximum membership principle was: $\alpha = \frac{n\beta - 1}{2\gamma(n-1)}$. Where, $\beta = \max_{1 \le i \le m}\{V_m\}, \gamma = \max_{1 \le i \le m, j \neq i}\{V_m\}$, and $\beta > \gamma$. (Zhu *et al.*, 2016)

①when $\alpha = +\infty$, maximum membership principle is complete validity.

②when $1 \le \alpha < +\infty$, maximum membership principle is comparative validity.

③when $0.5 \le \alpha < 1$, maximum membership principle is general validity.

④when $0 < \alpha < 0.5$, maximum membership principle is less validity.

⑤when $\alpha = 0$, maximum membership principle is invalidity.

(2) Multi-level Extension Synthesis Evaluation Method (MESE)

Extension is a new discipline founded by Chinese scholars headed by Professor Cai Wen, which is devoted to the study of the possibility of change (Extension) of things. Using "matter-element theory" as a quantitative measure Extension mathematics is the two main pillars of the tool, mainly used to solve the contradictions in real life(Xie Zhiming, 2012), the formal model as a carrier to study the possibility of things expanding. Extensible comprehensive evaluation is not limited by the index dimension, which may include many factors and different dimensions. The index type may be a qualitative index, a quantitative index, or a mixture of qualitative and quantitative indexes. In addition, the use of extension theory to conduct a comprehensive evaluation of strong logic, simple and easy to understand, a small amount of computation(Wang Ying, 2012).

The modeling process of building a comprehensive eco-industrial park evaluation model by MESE method is shown in Figure 2.8.

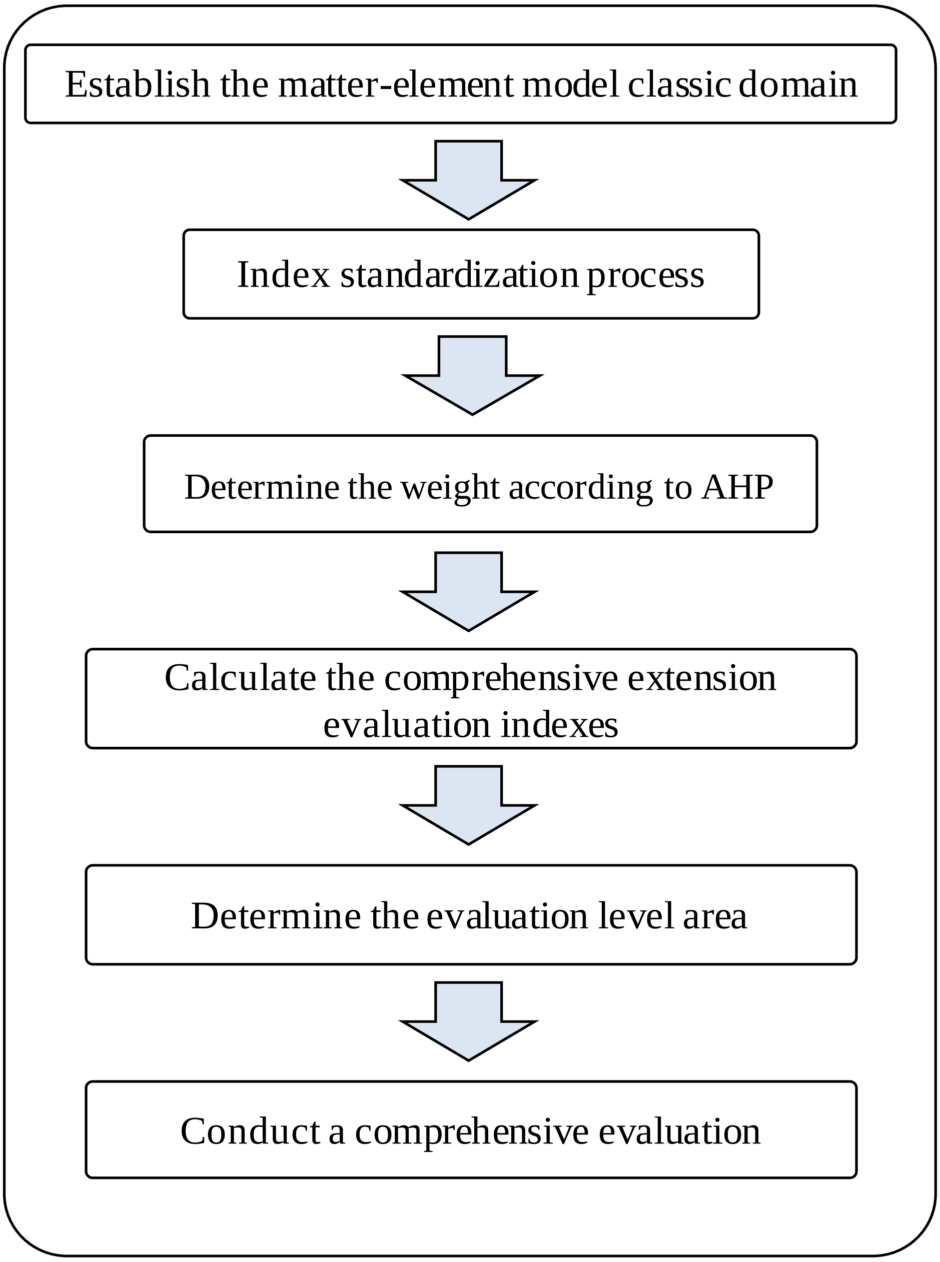

Figure 2.8 The modeling process of MESE

1) The Determination of Matter-element Model and Classical Domain

① Matter-element model

Matter-element is the basic element that describes things. The ordered three-tuple R=(N, C, V) is used to represent one-dimensional matter, where N is the thing, C is the feature of thing, V is the feature The three are called the three basic elements of matter-element(Xie Zhiming, 2012). According to the theory of matter element analysis, to evaluate the coordinated development degree and overall development level of eco-industrial park system, we must first analyze the various factors involved in the issue, based on the evaluation criteria of eco-industrial park, the cleaner production standards of key industries, the construction planning of different industrial parks Project index data and the corresponding yearbook statistics, given the magnitude of each feature factor, the establishment of eco-industrial park system coordinated development degree and the comprehensive development level matter element model:

$$R = \begin{pmatrix} N & C_1 & V_1 \\ & C_2 & V_2 \\ & \Lambda & \Lambda \\ & C_n & V_n \end{pmatrix}$$

Where, N represents the coordinated development degree and comprehensive development level of the eco-industrial park system. C_i(i= 1，2，…，n) indicate the characteristic factors affecting the coordinated development of the eco-industrial park system and the overall level of development. V_i(i= 1，2，…，n) are the range of values determined by C_i. about the level of the coordinated development and the comprehensive development *N*.

② Classic domain. To determine the range of values for each characteristic of C_i..

$$R_i = (N,C,V) = \begin{pmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \Lambda & \Lambda \\ & c_n & v_n \end{pmatrix} = \begin{pmatrix} N & c_1 & (a_1,b_1) \\ & c_2 & (a_2,b_2) \\ & \Lambda & \Lambda \\ & c_n & (a_n,b_n) \end{pmatrix}$$

Where, N represents the coordinated development degree and comprehensive development level. C_i(i= 1，2，…，n) are the characteristic factors that affect the coordinated development and the comprehensive development level. V_i(i= 1，2，…，n) are the level of the coordinated development and the comprehensive development *N*, that is the classical domain (a_i，b_i).

③ Determine to be judged material

The affect values of the degree of coordinated development were analyzed. And the analyzed data expressed as:

$$R_0 = (P_0, C, V) = \begin{pmatrix} P_0 & c_1 & v_1 \\ & c_2 & v_2 \\ & \Lambda & \Lambda \\ & c_n & v_n \end{pmatrix}$$

R_0 called material element of coordinated development level status, and P_0 called coordinated development level. C_i is P_0 characteristic parameters, V_i(i= 1，2，…，n) are the specific value of the parameter C_i.

2) Index Data Standardization

The so-called index data standardization is to use certain methods to convert the original data into dimensionless, sibling, plus standard data can be added(Xie Zhiming, 2012). There are many differences among the indexes, such as attribute, unit of measurement and numerical magnitude in the comprehensive evaluation index system. In addition, some indexes have clear index data, while some indexes are qualitative indexes. In the latter case, they should be relatively quantified by some scoring methods such as expert scoring method and comparative law between two methods(Xie Zhiming, 2012). Due to the fact that there are many comprehensive evaluation indexes and there is no clear boundary between "good" and "bad" indexes, to a large extent, there is some ambiguity(Xie Zhiming, 2012). In order to truly reflect the actual development of circular economy, Theory and practical needs, we combine the above matter-element model, we establish the corresponding correlation function, in the problems involved in this article, due to the different dimensions of the various factors, and some factors, the greater the expected value of the better, and some factor expectations Small better, so the correlation function should be different.

Assuming that the correlation function is linear, the fuzzy membership function of the correlation function is used to dimensionless each evaluation index and quantify the actual value of the original data of each evaluation index(Xie Zhiming, 2012). The specific steps are:

① Determine the upper and lower limits of each evaluation index, that is, the maximum and minimum of each index; determine the type of each index correlation function. For positive indexes, preclude the use of half-liter trapezoidal fuzzy membership function to quantify:

$$k(v_i)=\begin{cases}1 & v_i>b_i\\ \dfrac{v_i-a_i}{b_i-a_i} & v_i\in(a_i,b_i)\\ 0 & v_i<a_i\end{cases}$$

Where: $k(v_i)$ is the membership value of the status index of the i index; v_i is the status data of the i index; a_i is the lower limit of the i index; b_i is the upper limit of the i index.

② The inverse index is quantized using a semi-descending trapezoidal fuzzy membership function(Xie Zhiming, 2012), the formula is as follows:

$$k(v_i)=\begin{cases}0 & v_i>b_i\\ \dfrac{a_i-v_i}{a_i-b_i} & v_i\in(a_i,b_i)\\ 1 & v_i<a_i\end{cases}$$

The current status of each index v_i is brought into its corresponding fuzzy membership degree correlation function. The fuzzy membership degree quantified value of each index can be obtained after the actual value of the index is transformed by fuzzy transformation, and its value belongs to the range [0, 1] It is comparable because of elimination effects in different dimensions (Xie Zhiming, 2012).

(3) Grey Relational Clustering Method

Gray clustering is a whitening function which introduces the gray theory into the clustering analysis method. According to the whitening number that the clustering objects have for different clustering indexes, the gray numbers are classified according to several gray classes to determine which belongs to the clustering object a kind of multivariate analysis. The basic steps of gray relational clustering analysis are(Xie Zhiming, 2012):

Determining of the gray judgment model

↓

Determining of the optimal index set

↓

Standardization of index values

↓

Calculation of the whitening function for each gray index

↓

Calculation of the cluster weights and clustering coefficients

↓

Comprehensive evaluation

3. Construction of Comprehensive Evaluation Index System of Circular Economy

3.1 The Necessity of the Construction of Circular Economy Comprehensive Evaluation Index System

Eco-industrial park as a new industrial park combining the concept of circular economy and industrial ecology principles of construction, has not only become an effective way to achieve sustainable development, improving energy efficiency and the ecological environment quality in many countries, but also become an important carrier of implementing science-based, adjusting the industrial structure, accelerating the transformation and upgrading and constructing ecological civilization in China. Although the EIPs have made great progress in terms of planning and construction, and achieved some success in improving energy efficiency, reducing environmental pollution and improving environmental quality, but there are many problems in the development process, which restrict the stable operation and coordinated development and continuous improvement of the park, such as weak ecological relevance between enterprises, low resources and energy output rate, imperfect organizational structure, unclear construction goals and insufficient technical innovation. The causes of these problems are mainly due to the government agencies and park management department not paid enough attention to the coordinated development degree of EIPs, lacking of a practicable index system and assessment method for assessing the degree of sustainable development and comprehensive development level, which result in unable to fully grasp the operational state of the park and also can not formulate highly appropriate development strategy.

On the other hand, combining with the current development in China, enterprises independent of integrated industrial parks in many regions play an important role in the local economy. The methods for evaluating these enterprises are different from those in industrial parks. Therefore, it is necessary to construct a set of well-designed, operational evaluation index system. Enterprise as the basic unit of social and economic development, the implementation of circular economy for the regional and national implementation of circular economy has important influence. In order to better and faster to promote enterprises to develop circular economy, the enterprise's economic benefit, social benefit and ecological benefit evaluation enterprise circular economy as the basic starting point of the implementation effect, exploring enterprise of circular economy implementation effect evaluation index, method and the countermeasure of promoting enterprise implementation of circular economy, combined with the typical case of the circular economy demonstration enterprise specific evaluation, it is necessary to build a set of reasonable design, strong operational evaluation system.

3.2 Construction of Comprehensive Evaluation Index System of Eco-Industrial Park Circular Economy

3.2.1 Design Principle

Based on the principle of “three priorities and five combinations” put forward by relevant scholars regarding eco-industrial park comprehensive evaluation, the author summarizes the new “three priorities and five combinations” principle through a comparative analysis of related domestic literatures (Lei Ming, 2010).

“Three priorities” means to prioritize the generic statistical indexes, to prioritize the quantitative indexes, and to prioritize the reducing consumption and recycling indexes on the basis of ensuring data availability and evaluation accuracy.

“Five combinations” means to carry out five combinations in selecting and designing evaluation indexes, including the combination of policies and targets, the combination of functions and progressiveness, the combination of systematicness and hierarchy, the combination of dynamics and stability, and the combination of scientificity and operability.

(1) Combining of policy and goal

The setting of index system should not only give full consideration to the industrial policies of national and local industries, the requirements and policies of parks and enterprises for environmental protection and the guidelines for the planning of eco-industrial demonstration parks, but also comprehensively reflect the construction and development of different types of parks and systematically reflect The characteristics of the park ecosystem and the coordination between the various subsystems (Zhang Longjiang, 2011).

(2) Combining of functionality and advancement

The evaluation index system of eco-industrial park is a complex and systematic evaluation model. It should have the function of describing the status quo of the park, the function of evaluating the development potential of the park, the dynamic monitoring function of the park and the trend of the park and its future development

Predictive function (Zhang Longjiang, 2011). In addition, the evaluation index system should also reflect the average level of international advanced parks and the trend and direction of future development of the park to guide the future development of the park.

(3) Combining of systematicness and hierarchy

First of all, the construction of eco-industrial park is a complicated systematic project (Lu Qiuxia, 2006). The evaluation index system must comprehensively reflect all aspects of coordinated development of the park and the level of comprehensive development. It should cover the economic, resources, environment, ecology, society, Management of the six major aspects of the content; therefore, eco-industrial park must adopt the method of system engineering to design. Second, the evaluation index system itself should have a reasonable hierarchical structure. The Eco-Industrial Park consists of different enterprises that have a symbiotic relationship with each other. Enterprises are the basic units of industrial parks. The industrial chain between enterprises is the main body of the park. Therefore, The index system of industrial parks should consider different levels and aspects of enterprises, enterprises and parks (Zhang Longjiang, 2011).

(4) Combining of dynamic and stability

The eco-industrial park is developing dynamically. Its construction is a process of continuous improvement. The index system should give full consideration to the dynamic changes of the system, and can comprehensively reflect the status quo and development trend of the construction so as to facilitate the prediction and management. According to this principle, the index system of eco-industrial parks should take into account the sustainable development of economy, the continuous good environment, the continuous improvement of ecology, the continuous improvement of park management and the continuous improvement of society. Eco-Industrial Park is relatively stable, so the evaluation indexes should also reflect the status quo of Eco-Industrial Park and the current status of the industrial park.

(5) Combining of scientificity and maneuverability

The evaluation index is a comprehensive, systematic and scientific analysis of the eco-industrial park. The indexes should reflect the objectives, connotations, main characteristics and performance of eco-industrial parks. The data sources should be accurate and the treatment methods should be scientific. Although in theory (Zhang Longjiang, 2011), the broader the index system is, the more comprehensive and truthful it can reflect the development of integrated eco-industrial parks. However, this will result in the entire index system being cumbersome and inconvenient to use. Therefore, the evaluation The index system should give full consideration to the availability of data and the quantification of the difficulty of indexes, as well as the combination of quantitative and qualitative indexes to ensure that each index is observable, measurable, concise and comparable(Yuan Jiongliang, 2003).

3.2.2 Framework Determination

Eco-Industrial Park is a complex system composed of many factors such as economy, resources, environment, ecology and society. If one or a few indexes are difficult to comprehensively and objectively reflect the development status and future trends of eco-industrial parks, we need to carry out comprehensive evaluation from different sides and levels according to the types and characteristics of Eco-industrial Parks (Lei Ming, 2010).

Based on the idea of AHP, this paper divides the eco-industrial park comprehensive evaluation index system into four levels.

The first level is the target level, and the coordinated degree of development of the park system and the comprehensive level of development are taken as the overall objective of eco-industrial park evaluation.

The second layer is the standard layer, and the evaluation index is divided into six subsystems according to the above principles: economic development, resource utilization, environmental protection, ecological civilization, park management and social progress.

The third layer is the state layer, and the eco-industrial park evaluation status layer was divided into two categories using theoretical analysis and literature analysis: The first is the rigid index, which includes six aspects of economic strength, resource consumption, sewage intensity, ecological construction, management level and employment status, which reflects the status quo of eco-industrial park development and construction effect (Li Xiaopeng, 2008); the other is a flexible index, including the potential for economic development, recycling, pollution control, ecological improvement potential, infrastructure support capacity and happiness index 6 aspects, reflecting the stability of eco-industrial park development, Sustainability and coordination.

The fourth level is the variable level (index level), and the frequency of use of the system, and a number of evaluation indexes were determined accounting frequency statistics and expert advice method (Lei Ming, 2010).

3.2.3 Primary Selection and Screening of Evaluation Index

3.2.3.1 Evaluation Index Primary Selection

The determination of variable-level indexes is the key to establishing an index system (Zhu Li, 2011). Using frequency statistics and expert consultation methods, several alternative indexes of variable layer were selected according to the design principle of "three priority and five combination" index system, as shown in Table 3.1. The state level is denoted by *C* and the alternative index by M_{ij}.

Table 3.1 Primary Indexes of Comprehensive Eco-Industrial Park Index System

Status layer	**Variable layer and index code**
Economic Strength C1	Industrial output value M11,Industrial Added Value M12, Per-capital GDP M13, Per-capital Industrial Added Value M14, GDP Average Annual Growth Rate M15, Percentage of the Added Value of Tertiary Industry in GDP M16, Economic Output Density M17, Input-output ratioM18, Rate of Resources Output M19, Rate of Energy Output M110, Rate of Water Resources Output M111
Economic Development Potentials C2	Percentage of Scientific Research Input in GDP M21, Contribution Rate of Technological Progress to Industrial Output ValueM22, Percentage of High-tech Industry Output in Total Industrial Output Value M23, Advanced Technology Share M24, Product Category M25, Substitutability of Raw Materials Source M26, Waste Chain Completeness M27, Eco-industrial Chain Run Flexible M28, Enterprises Correlation M29, Mature Eco-industrial Chain Condition M210
Resource Consumption C3	Comprehensive Energy Consumption per Unit of Industrial Added Value M31, Comprehensive Energy Consumption Elasticity Coefficient M32, Fresh Water Consumption per Unit of Industrial Added Value M33, Fresh Water Consumption Elasticity Coefficient M34, Material Loss RateM35, Comprehensive Energy Consumption Elasticity Coefficient M36, Fresh Water Consumption Elasticity Coefficient M37
Recycling Degree C4	Energy Cascade UtilizationM41, Repetitiveness of Industrial Water M42, Comprehensive Utilization Ratio of Industrial Solid Wastes M43, Industrial Exhaust Recycling RateM44, Industrial Waste Heat Utilization rateM45, Industrial Pressure Recovery Rate M46
Sewage Discharge Intensity C5	Wastewater Production per Unit Product M51, Wastewater Production per Unit of Industrial Added Value M52, Solid Waste Production per Unit Product M53, Solid Waste Production per Unit of Industrial Added Value M54, COD Production per Unit of Industrial Added Value M55, SO_2 Emission per Unit of Industrial Added Value M56, Exhaust Discharge per Unit of Industrial Added Value M57, Smoke and Dust Discharge per Unit of Industrial Added Value M58, COD Emission Elasticity Coefficient M59, SO_2 Emission Elasticity Coefficient M510

Status layer	Variable layer and index code
Pollution Control C6	Rate of Industrial Wastewater Discharge Compliance M61, Rate of Industrial Wastewater Discharge Reduction M62, Rate of Industrial Exhaust Discharge Compliance M63, Rate of Industrial Exhaust Discharge Reduction M64, Rate of Industrial Solid Wastes Discharge Reduction M65, Rate of Household Wastes Hazard-free Treatment M66, Rate of Hazardous Wastes Treatment and Disposal M67, Rate of Main Air Pollutants Emission Compliance M68, Rate of Sewage Treatment Plant Effluent Quality Compliance M69, Average Regional Environmental Noise M610, Average Road Traffic Noise M611
Ecological Construction C7	Coverage Rate of Regulated Area of Dust and Smoke M71, Compliance Rate of Park Surface Water Environmental Quality M72, Compliance Rate of Park Groundwater Environmental Quality M73, Rate of Secondary Air Quality Standard Compliance M74, Rate of Park Greenery Coverage M75, Per-capita Public Green Area M76, Average Air Quality Rating M77, Average Water Environment Quality Level M78, Satisfaction of the Public toward the Environment M79
Ecological Improvement Potentials C8	Percentage of Environmental Protection in GDP M81, Percentage of Clean Energy in Total Energy M82, Environmentally Friendliness of ProductsM83, Ratio of Public Transport Sharing M84
Management Level C9	Establishment and Implementation of Environmental Management System M91, Park Environmental Report Preparation M92, Enterprise Cleaner Production Audit Implementation RateM93, Large-scale Enterprises 15014000 Certification RateM94, "Three simultaneous" Pass Rate M95, Completeness of Environmental Management System M96, Monitoring on Park Change M97, Eco-industrial Training M98
Infrastructure Supporting Capacity C10	Water Supply and Drainage Network Coverage Rate M101, Central Heating RateM102, Completeness of Supporting Infrastructures M103, Completeness of Information System M104, Completeness of Waste Collection System M105, Completeness of Waste Centralized Treatment Facilities M106, Percentage of Professionals in Environmental Administration Organizations M107
Employment C11	Ratio of the Number of Tertiary Industry Employees M111, Ratio of Employment Added by Developing Circular Economy M112, Re-employment Ratio M113
Happiness Index C12	Engel Coefficient M121, Social Security Coverage M122, Percentage of Culture-Education-Health Added Value in GDP M123

3.2.3.2 Evaluation Index Screening

According to the results of the expert consultation survey(questionnaire template shown in APPENDIX1), fill in the following tables with experts' opinions for screening the primary indexes.

(1) Screening of "economic strength" indexes

First, the analysis of the overlap of the primary indexes, the matrix of the relationship between the indexes listed in Table 3.2.

Table 3.2 Overlapping Analysis of Alternative Indexes C_1

	M11	M12	M13	M14	M15	M16	M17	M18	M19	M110	M111
M11	1	3	0	0	0	2	2	0	2	2	2
M12	3	1	0	2	2	0	0	2	0	0	0
M13	0	0	1	3	0	0	0	0	0	0	0
M14	0	2	3	1	0	0	0	0	0	0	0
M15	0	2	0	0	1	0	0	0	0	0	0
M16	2	0	0	0	0	1	0	0	0	0	0
M17	2	0	0	0	0	0	1	0	0	0	0
M18	0	2	0	0	0	0	0	1	0	0	0
M19	2	0	0	0	0	0	0	0	1	0	0
M110	2	0	0	0	0	0	0	0	0	1	0
M111	2	0	0	0	0	0	0	0	0	0	1
$\sum$	14	10	4	6	3	3	3	3	3	3	3

According to the judgment method given in Table 3.1, it can be seen from Table 3.2 that the columns M111 and M12 have the largest sum, indicating that the degree of overlap is large. The columns and sum of all the other indexes are greater than 1, indicating that the information between them partially overlap and need to be further compared Index screening principle analysis, give up the indexes do not meet the requirements. Overlapping indexes further screening analysis results in Table 3.2.

As can be seen from Table 3.3, after two-step screening analysis, the indices to be retained are M14 per capita industrial added value, M15 average annual GDP growth rate, M16 tertiary industry added value, M17 economic output density, Output rate M110, water yield M111.

Table 3.3 "Economic Strength" Screening Results

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M11	overlap	non-conformance of comparability principle	×
M12	overlap	non-conformance of necessity principle	×
M13	overlap	non-conformance of necessity principle	×
M14	overlap	accord with principle of necessity and comparability	√
M15	overlap	accord with principle of necessity	√
M16	overlap	accord with principle of necessity	√
M17	overlap	accord with principle of necessity and comparability	√
M18	overlap	non-conformance of operability principle	×
M19	overlap	accord with principle of necessity and comparability	×
M110	overlap	accord with principle of necessity and comparability	√
M111	overlap	accord with principle of necessity and comparability	√

(2) Index Screening of "Economic Development Potential"

Table 3.4 Overlapping Analysis of Alternative Indexes C_2

	M21	M22	M23	M24	M25	M26	M27	M28	M29	M210
M21	1	0	0	0	0	0	0	0	0	0
M22	0	1	0	0	0	0	0	0	0	0
M23	0	0	1	0	0	0	0	0	0	0
M24	0	0	0	1	0	0	0	0	0	0
M25	0	0	0	0	1	0	0	0	0	0
M26	0	0	0	0	0	1	0	0	0	0
M27	0	0	0	0	0	0	1	0	0	2
M28	0	0	0	0	0	0	0	1	0	0
M29	0	0	0	0	0	0	0	0	1	0
M210	0	0	0	0	0	0	2	0	0	1
∑	1	1	1	1	1	1	3	1	1	3

As can be seen from Table 3.4-3.5, after two-step screening analysis, the indexes that should be retained are the ratio of research input to GDP M21, output value of high-tech industries as a share of total industrial output value M23, degree of waste chain M27, alternative source of raw materials M26, inter-enterprise relevance M29.

Table 3.5 Screening Results of "Economic Development Potential"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M21	independence	accord with principle of necessity and comparability	√
M22	independence	non-conformance of operability principle	×
M23	independence	accord with principle of necessity and comparability	√
M24	independence	non-conformance of principle of operability and comparability	×
M25	independence	non-conformance of necessity principle	×
M26	independence	accord with principle of operability	√
M27	independence	accord with principle of necessity and comparability	√
M28	independence	non-conformance of principle of operability and comparability	×
M29	independence	accord with principle of necessity and comparability	√
M210	overlap	non-conformance of necessity principle	×

(3) Index Screening of "resource consumption"

It can be seen from Table 3.6-3.7 that after two-step screening analysis, the indexes to be retained are the integrated energy consumption per unit of industrial added value M31, the fresh water consumption per unit industrial added value M33, the comprehensive energy consumption elasticity coefficient M36 and the comprehensive water consumption elasticity coefficient M37.

Table 3.6 Overlapping Analysis of Alternative Indexes C_3

	M31	M32	M33	M34	M35	M36	M37
M31	1	3	0	0	0	0	0
M32	3	1	0	0	0	0	0
M33	0	0	1	2	0	0	0
M34	0	0	2	1	0	0	0
M35	0	0	0	0	1	0	0
M36	0	0	0	0	0	1	2
M37	0	0	0	0	0	2	1
∑	4	4	3	3	1	3	3

Table 3.7 Index Screening Results of Resource Consumption

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M31	overlap	accord with principle of necessity and comparability	√
M32	overlap	accord with principle of necessity and comparability	×
M33	overlap	accord with principle of necessity and comparability	√
M34	overlap	accord with principle of necessity and comparability	×
M35	independence	non-conformance of principle of operability and comparability	×
M36	overlap	accord with principle of necessity and comparability	√
M37	overlap	accord with principle of necessity and comparability	√

(4) Index Screening of “Recycling”

It can be seen from Table 3.8-3.9 that after two-step screening analysis, the indexes to be retained are M42 for industrial water reuse and M43 for comprehensive utilization of industrial solid waste.

Table 3.8 Overlapping Analysis of Alternative Indexes C_4

	M41	M42	M43	M44	M45	M46
M41	1	0	0	0	0	0
M42	0	1	0	0	0	0
M43	0	0	1	0	0	0
M44	0	0	0	1	0	0
M45	0	0	0	0	1	0
M46	0	0	0	0	0	1
∑	1	1	1	1	1	1

Table 3.9 Index Screening Results of "Recycling"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M41	independence	non-conformance of operability principle	×
M42	independence	accord with principle of necessity and comparability	√
M43	independence	accord with principle of necessity and comparability	√
M44	independence	non-conformance of principle of operability and comparability	×
M45	independence	non-conformance of principle of operability and comparability	×
M46	independence	non-conformance of principle of operability and comparability	×

(5) Index Screening of "Emission intensity"

As can be seen from Table 3.10-3.11, after two-step screening analysis, the indexes to be retained are the amount of waste water produced per unit of industrial added value M52, unit output value of industrial solid waste M54, unit output value of industrial added value M55, unit industrial added value SO_2 emissions M56, COD emission elastic coefficient M59, SO_2 emission elastic coefficient M510.

Table 3.10 Overlapping Analysis of Alternative Indexes C_5

	M51	M52	M53	M54	M55	M56	M57	M58	M59	M510
M51	1	3	0	0	0	0	0	0	0	0
M52	3	1	0	0	0	0	0	0	0	0
M53	0	0	1	3	0	0	0	0	0	0
M54	0	0	3	1	0	0	0	0	0	0
M55	0	0	0	0	1	0	0	0	2	0
M56	0	0	0	0	0	1	3	2	0	2
M57	0	0	0	0	0	3	1	0	0	2
M58	0	0	0	0	0	2	0	1	0	0
M59	0	0	0	0	2	0	0	0	1	0
M510	0	0	0	0	0	2	2	0	0	1
∑	4	4	4	4	3	8	6	3	3	5

Table 3.11 Index Screening Results of "Emission Intensity"

Index number	Index relationship	Reason explanation	Retain(√) or Abandon(×)
M51	overlap	accord with principle of necessity and comparability	×
M52	overlap	accord with principle of necessity and comparability	√
M53	overlap	accord with principle of necessity and comparability	×
M54	overlap	accord with principle of necessity and comparability	√
M55	overlap	accord with principle of necessity	√
M56	overlap	accord with principle of necessity and comparability	√
M57	overlap	non-conformance of necessity principle	×
M58	overlap	non-conformance of necessity principle	×
M59	overlap	accord with principle of necessity and comparability	√
M510	overlap	accord with principle of necessity and comparability	√

(6) Index Screening of “Pollution control”

As can be seen from Table 3.12-3.13, after two-step screening analysis, the indexes that should be retained are the industrial wastewater discharge compliance rate M61, the industrial wastewater discharge reduction rate M62, the industrial solid waste emission reduction rate M65 and the domestic garbage decontamination rate M66. Waste disposal rate M67, main air pollutant discharge compliance rate M68, sewage treatment plant effluent quality compliance rate M69, regional average environmental noise M610, road traffic noise average M611.

Table 3.12 Overlapping Analysis of Alternative Indexes C_6

	M61	M62	M63	M64	M65	M66	M67	M68	M69	M610	M611
M61	1	2	0	0	0	0	0	0	0	0	0
M62	2	1	0	0	0	0	0	0	0	0	0
M63	0	0	1	2	0	0	0	3	0	0	0
M64	0	0	2	1	0	0	0	3	0	0	0
M65	0	0	0	0	1	0	0	0	0	0	0
M66	0	0	0	0	0	1	0	2	0	0	0
M67	0	0	0	0	0	0	1	0	0	0	0
M68	0	0	3	3	0	2	0	1	0	0	0
M69	0	0	0	0	0	0	0	0	1	0	0
M610	0	0	0	0	0	0	0	0	0	1	0
M611	0	0	0	0	0	0	0	0	0	0	1
∑	3	3	6	6	1	3	1	9	1	1	1

Table 3.13 Index Screening Results of "Pollution Control"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M61	overlap	accord with principle of necessity and comparability	√
M62	overlap	accord with principle of necessity and comparability	√
M63	overlap	non-conformance of principle operability and pertinence	×
M64	overlap	non-conformance of principle operability and pertinence	×
M65	independence	accord with principle of necessity	√
M66	independence	accord with principle of necessity and comparability	√
M67	independence	accord with principle of necessity and comparability	√
M68	overlap	accord with principle of necessity and comparability	√
M69	independence	accord with principle of necessity and comparability	√
M610	independence	accord with principle of necessity and comparability	√
M611	independence	accord with principle of necessity and comparability	√

(7) Index Screening of “Ecological construction”

As can be seen from Table 3.14-3.15, after two-step screening analysis, the indexes that should be retained are the coverage of smoke-dust control area M71, the air quality standard of second grade M74, the park's green coverage M75, and the public's satisfaction with the environment M79.

Table 3.14 Overlapping Analysis of Alternative Indexes C_7

	M61	M62	M63	M64	M65	M66	M67	M68	M69
M71	1	2	0	0	0	0	0	0	0
M72	2	1	0	0	0	0	0	3	0
M73	0	0	1	2	0	0	0	3	0
M74	0	0	2	1	0	2	2	0	0
M75	0	0	0	0	1	0	0	0	0
M76	0	0	0	0	2	1	0	0	0
M77	0	0	0	2	0	0	1	0	0
M78	0	3	3	0	0	0	0	1	0
M79	0	0	0	0	0	0	0	0	1
∑	3	6	6	5	3	3	3	7	1

Table 3.15 Index Screening Results of “Ecological Construction”

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M71	independence	accord with principle of necessity and comparability	√
M72	overlap	non-conformance of operability principle	×
M73	overlap	non-conformance of operability principle	×
M74	overlap	accord with principle of necessity and comparability	√
M75	overlap	accord with principle of necessity	√
M76	overlap	non-conformance of necessity principle	×
M77	overlap	non-conformance of necessity principle	×
M78	overlap	accord with principle of necessity and comparability	×
M79	independence	accord with principle of necessity and comparability	√

(8) Index Screening of “Ecological Improvement Potential”

It can be seen from Table 3.16-3.17 that after two-step screening analysis, the indexes that should be retained are M81 of total investment in environmental protection, M82 of clean energy and M84 of public transport.

Table 3.16 Overlapping Analysis of Alternative Indexes C_8

	M81	M82	M83	M84
M81	1	0	0	0
M82	0	1	0	0
M83	0	0	1	0
M84	0	0	0	1
∑	1	1	1	1

Table 3.17 Index Screening Results of "Ecological Improvement Potential"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M81	independence	accord with principle of necessity and comparability	√
M82	independence	accord with principle of necessity and comparability	√
M83	independence	non-conformance of principle of necessity and operability	×
M84	independence	accord with principle of necessity and comparability	√

(9) Index Screening of "Management level"

As can be seen from Table 3.18-3.19, after two-step screening analysis, the indexes that should be retained are M92 for the preparation of regional environmental reports, M96 for environmental management systems, M97 for monitoring park change and M98 for knowledge of ecological industry.

Table 3.18 Overlapping Analysis of Alternative Indexes C_9

	M91	M92	M93	M94	M95	M96	M97	M98
M91	1	2	0	0	0	2	0	0
M92	2	1	0	0	0	0	0	0
M93	0	0	1	2	0	0	0	0
M94	0	0	2	1	0	2	0	0
M95	0	0	0	0	1	0	0	0
M96	2	0	0	0	2	1	0	0
M97	0	0	0	0	0	0	1	0
M98	0	0	0	0	0	0	0	1
∑	5	3	3	3	3	5	1	1

Table 3.19 Index Screening Results of "Management Level"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M91	overlap	non-conformance of pertinence principle	×
M92	overlap	accord with principle of necessity and comparability	√
M93	overlap	non-conformance of operability principle	×
M94	overlap	non-conformance of operability principle	×
M95	overlap	non-conformance of necessity principle	×
M96	overlap	accord with principle of necessity and comparability	√
M97	independence	accord with principle of necessity and comparability	√
M98	independence	accord with principle of necessity and comparability	√

(10) Index Screening of "Infrastructure support capacity"

As can be seen from Table 3.20-3.21, after two-step screening analysis, the indexes that should be retained are M103 for infrastructure improvement, M104 for information system improvement, and M107 for professionals in environmental management agencies.

Table 3.20 Overlapping Analysis of Alternative Indexes C_{10}

	M101	M102	M103	M104	M105	M106	M107
M101	1	0	0	0	0	0	0
M102	0	1	2	0	0	0	0
M103	0	2	1	2	2	2	0
M104	0	0	2	1	0	2	2
M105	0	0	2	0	1	0	0
M106	0	0	2	0	2	1	0
M107	0	0	0	2	0	0	1
∑	1	3	9	5	5	5	3

Table 3.21 Index Screening Results of "Infrastructure support capacity"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M101	independence	non-conformance of necessity principle	×
M102	overlap	non-conformance of necessity principle	×
M103	overlap	accord with principle of necessity	√
M104	overlap	accord with principle of necessity	√
M105	overlap	Repeat with pollution control index，non-conformance of necessity principle	×
M106	overlap	Repeat with pollution control index，non-conformance of necessity principle	×
M107	overlap	accord with principle of necessity	√

(11) Index Screening of "employment status"

As can be seen from Table 3.22-3.23, after two-step screening analysis, the indexes to be retained are the employment ratio M111 in the tertiary industry and the employment rate M112 in developing the recycling economy.

Table 3.22 Overlapping Analysis of Alternative Indexes C_{11}

	M111	M112	M113
M111	1	0	0
M112	0	1	2
M113	0	2	1
∑	1	3	3

Table 3.23 Index Screening Results of "Employment Status"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M111	independence	accord with principle of necessity	√
M112	overlap	accord with principle of necessity	√
M113	overlap	non-conformance of necessity principle	×

(12) Index Screening of "Happiness index"

It can be seen from Table 3.24-3.25 that after two-step screening analysis, indexes should be retained Engel's coefficient M121 and social security coverage M122.

Table 3.24 Overlapping Analysis of Alternative Indexes C_{11}

	M111	M112	M113
M121	1	0	0
M122	0	1	0
M123	0	0	1
∑	1	1	1

Table 3.25 Index Screening Results of "Happiness Index"

Index number	**Index relationship**	**Reason explanation**	**Retain(√) or Abandon(×)**
M121	independence	accord with principle of necessity	√
M122	independence	accord with principle of necessity	√
M123	independence	non-conformance of principle of necessity and operability	×

3.2.4 Comprehensive Evaluation Index System of Eco-Industrial Park Circular Economy

After screening and analysis of the primary index, unnecessary indexes are removed, and the indexes that remain are established to construct the comprehensive evaluation index system shown in Table 3.26.

Table 3.26 Comprehensive Evaluation Index System of Eco-industrial Park

Target Layer A	**Criterion Layer B**	**State Layer C**	**Variable Layer M**
Coordinated Development Degree and Comprehensive Development Level of the Park System	Economic Development B1	Economic Strength, C1	Per-capital Industrial Added Value (ten thousand yuan/capital) M1↑
			GDP Average Annual Growth Rate (%) M2↑
			Percentage of the Added Value of Tertiary Industry in GDP (%) M3↑
			Economic Output Density (100 Million yuan/sq.km.) M4↑
			Rate of Energy Output (10 Thousand yuan/tce) M5↑
			Rate of Water Resources Output (10 Thousand yuan/m^3) M6↑
		Economic Development Potentials C2	Percentage of Scientific Research Input in GDP (%)M7↑
			Percentage of High-tech Industry Output in Total Industrial Output Value (%) M8↑
			Enterprises Correlation M9↑
			Waste Chain Completeness M10↑
			Substitutability of Raw Materials Source M11↑
	Resource Utilization B2	Resource Consumption C3	Comprehensive Energy Consumption per Unit of Industrial Added Value (tce/10 Thousand yuan)M12↓
			Fresh Water Consumption per Unit of Industrial Added Value (m^3/10 Thousand yuan) M13↓
			Comprehensive Energy Consumption Elasticity Coefficient M14↓
			Fresh Water Consumption Elasticity Coefficient M15↓
		Recycling Degree C4	Repetitiveness of Industrial Water (%) M16↑
			Comprehensive Utilization Ratio of Industrial Solid Wastes (%) M17↑
	Environmental Protection B3	Sewage Discharge Intensity C5	Wastewater Production per Unit of Industrial Added Value (t/10 Thousand yuan) M18↓
			Solid Waste Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M19↓
			COD Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M20↓
			SO_2 Emission per Unit of Industrial Added Value (kg/10 Thousand yuan) M21↓
			COD Emission Elasticity Coefficient M22↓
			SO_2 Emission Elasticity Coefficient M23↓

(Continued)

Target Layer A	Criterion Layer B	State Layer C	Variable Layer M
Coordinated Development Degree and Comprehensive Development Level of the Park System	Environmental Protection B3	Pollution Control C6	Rate of Industrial Wastewater Discharge Compliance (%) M24↑
			Rate of Industrial Wastewater Discharge Reduction (%) M25↑
			Rate of Main Air Pollutants Emission Compliance (%)M26↑
			Rate of Industrial Solid Wastes Discharge Reduction (%) M27↑
			Rate of Household Wastes Hazard-free Treatment (%) M28↑
			Rate of Hazardous Wastes Treatment and Disposal (%)M29↑
			Rate of Sewage Treatment Plant Effluent Quality Compliance (%) M30↑
			Average Regional Environmental Noise (db) M31↓
			Average Road Traffic Noise (db) M32↓
	Eco-friendly B4	Ecological Construction C7	Coverage Rate of Regulated Area of Dust and Smoke (%) M33↑
			Rate of Secondary Air Quality Standard Compliance (%) M34↑
			Rate of Park Greenery Coverage(%) M35↑
			Satisfaction of the Public toward the Environment (%) M36↑
		Ecological Improvement Potentials C8	Percentage of Environmental Protection in GDP (%) M37↑
			Percentage of Clean Energy in Total Energy (%) M38↑
			Ratio of Public Transport Sharing (%) M39↑
	Park Administration B5	Management Level C9	Park Environmental Report Preparation M40↑
			Completeness of Environmental Management System M41↑
			Monitoring on Park Change M42↑
			Eco-industrial Training M43↑
		Infrastructure Supporting Capacity C10	Completeness of Supporting InfrastructuresM44↑
			Completeness of Information System M45↑
			Percentage of Professionals in Environmental Administration Organizations (%) M46↑
	Social Progress B6	Employment C11	Ratio of the Number of Tertiary Industry Employees (%) M47↑
			Ratio of Employment Added by Developing Circular Economy (%) M48↑
		Happiness Index C12	Engel Coefficient (%) M49↓
			Social Security Coverage (%) M50↑

Note: ↑positive index, ↓inverse index

3.2.5 Evaluation Index Significance

Economic Strength *C_1*:

(1) Per-capital Industrial Added Value (ten thousand yuan/capital)

Index Explanation: The per-capita industrial added value refers to the industrial added value created by the per-capita employment of the industrial park during the reporting period. The industrial added value is the final result of an industrial production activity performed in monetary terms by an industrial enterprise during the reporting period and is a newly added value in the production of the enterprise.

Calculation formula:

$$\text{Per-capital Industrial Added Value} = \frac{\text{Industrial Added Value（ten thousand yuan）}}{\text{employment（capital）}}$$

(2) GDP Average Annual Growth Rate (%)

Index Explanation: GDP average annual growth rate refers to the park during the reporting period GDP relative to the previous year's value-added and the previous year's percentage of GDP

Calculation formula:

$$\text{GDP Average Annual Growth Rate} = \frac{\text{current years GDP（ten thousand yuan）} - \text{last years GDP（ten thousand yuan）}}{\text{last years GDP（ten thousand yuan）}}$$

(3) Percentage of the Added Value of Tertiary Industry in GDP (%)

Index Explanation: The ratioof the tertiary industry in GDP is an index of the degree of the industrialization of the advanced level, used to reflect the quality of urban industrial structure. This index not only reflects the degree of service-oriented industrial structure in the country or the region, but also serves as an internationally accepted benchmark for comparing and evaluating the modernization of the economic structure in a country or a region. The higher the index shows that the stronger the ability of circular economy development.

Calculation formula:

$$\text{Percentage of the Added Value of Tertiary Industry in GDP} = \frac{\text{Added Value of Tertiary Industry（ten thousand yuan）}}{\text{GDP（ten thousand yuan）}} \times 100\%$$

(4) Economic Output Density (100 Million yuan/sq.km.)

Index Explanation: Density of economic output, also called GDP density or land productivity, refers to the percentage of the GDP of the entire park and the area of industrial land during the reporting period, and comprehensively reflects the contribution of land to the economic growth of the park. The higher the index is the better the economic development in the evaluation area.

Calculation formula:

$$\text{Economic Output Density} = \frac{\text{Total output value(100 Million yuan)}}{\text{Industrial land（sq.km.）}}$$

(5) Rate of Energy Output (10 Thousand yuan/tce)

Index Explanation: Refers to the percentage of GDP and energy consumption of the entire park during the reporting period, which comprehensively reflects the contribution of energy to the economic growth of the park.

Calculation formula:

$$\text{Rate of Energy Output} = \frac{\text{Total output value(100 Million yuan)}}{\text{Energy consumption（tce）}} \times 100\%$$

(6) Rate of Water Resources Output (10 Thousand yuan/m^3)

Index Explanation: Refers to the percentage of GDP and water resources in the entire zone during the reporting period, which comprehensively reflects the contribution of water resources to the economic growth of the park.

Calculation formula:

$$\text{Rate of Water Resources Output} = \frac{\text{Total output value(100 Million yuan)}}{\text{Fresh water consumption（m3）}} \times 100\%$$

Economic Development Potentials C_2:

(1) Percentage of Scientific Research Input in GDP (%)

Index Explanation: Refers to the percentage of research and development (R&D) expenditures on regional GDP.

Calculation formula:

$$\text{Percentage of Scientific Research Input in GDP} = \frac{\text{Expenditure for R \& D(100 Million yuan)}}{\text{Total output value(100 Million yuan)}} \times 100\%$$

(2) Percentage of High-tech Industry Output in Total Industrial Output Value (%)

Index Explanation: Refers to the ratio of the output value of hi-tech industries in the zone to the total industrial output value in the region during the reporting period, which reflects the contribution rate of high-tech industries to the total output value of industrial parks in the region.

Calculation formula:

$$\text{Percentage of High-tech Industry Output in Total Industrial Output Value} = \frac{\text{High-tech Industry Output Value(ten thousand yuan)}}{\text{Total Industrial Output Value(ten thousand yuan)}} \times 100\%$$

(3) Enterprises Correlation

Index Explanation: Park ecological association between enterprises refers to the degree of contact between enterprises in the park.

Calculation formula:

$$C_e = \frac{L_e}{S(S-1)/2}$$

C_e is the degree of ecological connection between enterprises in the park, L_e is the park eco-industrial chain number, S is the number of enterprises in the park.

(4) Waste Chain Completeness

Index Explanation: The degree of waste chain integrity mainly considers the establishment and operation of waste water, waste gas and solid waste collection systems, as well as the degree of completeness of the waste chain (Lei Ming, 2010).

(5) Substitutability of Raw Materials Source

Index Explanation: This index is used to evaluate the substitutability of the sources of raw materials. The greater the value of the index is the more sources of raw materials are available; the smaller the value is the less the sources of raw materials (Lei Ming, 2010).

Resource Consumption C_3:

(1) Comprehensive Energy Consumption per Unit of Industrial Added Value (tce/10 Thousand yuan)

Index Explanation: Refers to the statistical reporting period, the park integrated energy consumption and the unit of industrial use during the ratio of industrial added value.

The comprehensive energy consumption in the park refers to the total amount of all kinds of energy (coal, electricity, oil, etc.) actually consumed by the energy consuming unit in the statistical reporting period after the conversion according to the prescribed calculation methods and units. For enterprises, comprehensive energy consumption refers to the total energy consumption of major production systems, auxiliary production systems and subsidiary production systems during the reporting period.

Calculation formula:

$$\text{Comprehensive Energy Consumption per Unit of Industrial Added Value} = \frac{\text{Comprehensive Energy Consumption(tce)}}{\text{Industrial Added Value(10 Thousand yuan)}}$$

(2) Fresh Water Consumption per Unit of Industrial Added Value (m^3/10 Thousand yuan)

Index Explanation Refers to the statistical reporting period, the park industrial fresh water consumption and the energy unit of industrial value added during the period ratio.

The industrial fresh water consumption in the industrial zone refers to the amount of fresh water used for production and daily life in the factory (excluding domestic wastewater mixed with domestic sewage separately measured) in the reporting period, which is equal to the amount of water taken by the enterprise from urban tap water and the amount of self-owned water companies.

Calculation formula:

$$\text{Fresh Water Consumption per Unit of Industrial Added Value} = \frac{\text{Fresh Water Consumption}\ (\text{m}^3)}{\text{Industrial Added Value}\ (\text{10 Thousand yuan})}$$

(3) Comprehensive Energy Consumption Elasticity Coefficient

Index Explanation: Refers to the total energy consumption in the park during the reporting period the ratio of industrial added value growth rate. Total energy consumption growth rate of comprehensive energy consumption during the reporting period refers to the total energy consumption of the park during the reporting period compared with the previous year's total energy consumption value added to the previous year's total energy consumption percentage

Calculation formula:

$$\text{Comprehensive Energy Consumption Growth Rate} = \frac{\text{Energy Consumption current years}(tce) - \text{Energy Consumption last years}(tce)}{\text{Energy Consumption last years}(tce)} \times 100\%$$

$$\text{Comprehensive Energy Consumption Elasticity Coefficient} = \frac{\text{Comprehensive energy consumption growth rate}}{\text{Industrial added value growth rate}}$$

(4) Fresh Water Consumption Elasticity Coefficient

Index Explanation: Refers to the ratioof the growth rate of industrial fresh water volume and industrial added value growth rate during the reporting period. The growth rate of industrial fresh water refers to the increase of industrial fresh water volume in the reporting period relative to the industrial fresh water volume of the previous year and the percentage of fresh industrial water volume in the previous year

Calculation formula:

$$\text{Fresh water consumption growth rate} = \frac{\text{Fresh water consumption current years}(m^3) - \text{Fresh water consumption last years}(m^3)}{\text{Fresh water consumption last years}(m^3)} \times 100\%$$

$$\text{Fresh Water Consumption Elasticity Coefficient} = \frac{\text{Fresh water consumption growth rate}}{\text{Industrial added value growth rate}}$$

Recycling Degree C_4:

(1) Repetitiveness of Industrial Water (%)

Index Explanation: Refers to the percentage of industrial water reuse accounted for the total amount of industrial water.

Repetitive industrial water consumption: Refers to the amount of water repeatedly used in the production water of enterprises during the reporting period, including the recycled water, the water used in multiple usage and the water used in cascade (including the reprocessed amount after treatment).

Total industrial water consumption refers to the amount of water used for production and living in the factory area of a factory during the reporting period, which is equal to the sum of the fresh water used in industry and the industrial water used repeatedly.

Calculation formula:

$$\text{Repetitiveness of Industrial Water} = \frac{\text{Industrial water reuse (m}^3\text{)}}{\text{Total industrial water (m}^3\text{)}} \times 100\%$$

(2) Comprehensive Utilization Ratio of Industrial Solid Wastes (%)

Index Explanation: Refers to the comprehensive utilization of industrial solid waste as a percentage of industrial solid waste generated (including the comprehensive utilization of previous years storage) percentage.

The comprehensive utilization of industrial solid wastes refers to the amount of solid wastes extracted from solid wastes or converted into usable resources, energy and other raw materials by recycling, processing, recycling and exchange during the reporting period In previous years, the storage volume of industrial solid waste), such as agricultural fertilizer, production of building materials, road construction. The comprehensive utilization is the unit of the original solid waste generated statistics.

Calculation formula:

$$\text{Comprehensive Utilization Ratio of Industrial Solid Wastes} = \frac{\text{Industrial solid waste comprehensive utilization(t)}}{\text{Industrial solid waste production(t)} + \text{Comprehensive utilization of previous years storage(t)}} \times 100\%$$

Sewage Discharge Intensity *C_5*:

(1) Wastewater Production per Unit of Industrial Added Value (t/10 Thousand yuan) Index Explanation: Refers to the park million yuan industrial added value of industrial waste generated. Does not include the use of enterprise cascades of wastewater and domestic residents discharge of domestic wastewater, including wastewater treatment business reuse

Calculation formula:

$$\text{Wastewater Production per Unit of Industrial Added Value} = \frac{\text{Wastewater production(t)}}{\text{Industrial added value (10 Thousand yuan)}}$$

(2) Solid Waste Production per Unit of Industrial Added Value (t/10 Thousand yuan)

Index Explanation: Refers to the total industrial solid waste generated from industrial added value of 10 thousand yuan in the park

Calculation formula:

$$\text{Solid Waste Production per Unit of Industrial Added Value} = \frac{\text{solid waste produced(t)}}{\text{Industrial added value (10 Thousand yuan)}}$$

(3) COD Production per Unit of Industrial Added Value (kg/10 Thousand yuan)

Index Explanation: Park million yuan industrial added value of waste water pollutants required for chemical oxygen demand. Including direct discharge of wastewater and wastewater discharged by enterprises or municipal wastewater treatment plant

Calculation formula:

$$\text{COD Production per Unit of Industrial Added Value} = \frac{\text{COD discharge(kg)}}{\text{Industrial Added Value(10 Thousand yuan)}} \times 100\%$$

(4) SO_2 Emission per Unit of Industrial Added Value (kg/10 Thousand yuan)

Index Explanation: Refers to the park every 10,000 yuan industrial added value to the atmosphere of SO_2 emissions.

Calculation formula:

$$\text{SO2 Emission per Unit of Industrial Added Value} = \frac{SO_2\text{discharge (kg)}}{\text{Industrial Added Value(10 Thousand yuan)}} \times 100\%$$

(5) COD Emission Elasticity Coefficient

Index Explanation: In the report period, the ratio of COD emission growth rate and industrial added value growth rate in the park. COD emissions growth rate refers to the reporting period the park COD emissions relative to the previous year's COD emissions and the difference between the previous year, the percentage of COD emissions

Calculation formula:

$$\text{COD Emission growth rate} = \frac{\text{COD Emission current year} - \text{COD Emission last years}}{\text{COD Emission last years}} \times 100\%$$

$$\text{COD Emission Elasticity Coefficient} = \frac{\text{COD Emission growth rate}}{\text{Industrial added value growth rate}}$$

(6) SO_2 Emission Elasticity Coefficient

Index Explanation: During the reporting period, the ratio of SO_2 emission growth rate to industrial added value growth rate in the park. SO_2 emission growth rate refers to the reporting period the park SO_2 emissions relative to the previous year's SO_2 emissions and the difference between the previous year, the percentage of SO_2 emissions from wastewater.

Calculation formula:

$$\text{SO}_2 \text{ emission growth rate} = \frac{\text{current year's SO}_2 \text{ emission value} - \text{l}\textit{ast} \text{ year's SO}_2 \text{ emission value}}{\text{l}\textit{ast} \text{ year's SO}_2 \text{ emission value}} \times 100\%$$

$$\text{SO2 Emission Elasticity Coefficient} = \frac{\text{SO}_2 \text{ emission growth rate}}{\text{Industrial added value growth rate}} \times 100\%$$

Pollution Control C_6:

(1) Rate of Industrial Wastewater Discharge Compliance (%)

Index Explanation: Industrial wastewater discharge compliance rate refers to the percentage of industrial wastewater discharge as a percentage of industrial wastewater discharge.

Calculation formula:

$$\text{Rate of Industrial Wastewater Discharge Compliance} = \frac{\text{Industrial Wastewater Discharge Compliance}}{\text{Total Industrial Wastewater Discharge}} \times 100\%$$

(2) Rate of Industrial Wastewater Discharge Reduction (%)

Index Explanation: The reduction rate of industrial wastewater discharge refers to the percentage of the difference between the industrial wastewater discharge reduction in the park and the industrial wastewater discharge volume in the previous year to the industrial wastewater discharge volume in the previous year.

Calculation formula:

$$\text{Rate of Industrial Wastewater Discharge Reduction} = \frac{\text{last year's wastewater emission value} - \text{current year's wastewater emission value}}{\text{last year's wastewater emission value}} \times 100\%$$

(3) Rate of Main Air Pollutants Emission Compliance (%)

Index Explanation: The main air pollutant discharge rate compliance refers to the percentage of the main air pollutant discharge standards as the major air pollutant emissions.

The main air pollutants include SO_2, suspended particulate matter (TSP) such as dust, smoke, PM_{10} and $PM_{2.5}$, NOx, volatile organic compounds (VOCs) such as benzene, hydrocarbons and formaldehyde, photochemical oxides (Eg ozone O_3) and greenhouse gases (eg carbon dioxide, methane, chlorofluorocarbons)

Calculation formula:

$$\text{Rate of Main Air Pollutants Emission Compliance} = \frac{\text{Major air pollutants discharge standards}}{\text{Major air pollutant emissions}} \times 100\%$$

Evaluation Basis: According to the ambient air quality standards (GB3095-1996) in the basic items of ambient air pollutant concentration limits and other items concentration limit level set shall prevail.

(4) Rate of Industrial Solid Wastes Discharge Reduction (%)

Index Explanation: Industrial Solid Waste Emission Reduction Rate refers to the percentage difference between the industrial solid waste emissions from industrial parks in the reporting period and the industrial solid waste emissions in the previous year from the previous year's industrial solid waste emissions.

Calculation formula:

$$\text{Rate of Industrial Solid Wastes Discharge Reduction} = \frac{\text{current year's soild waste discharge} - \text{last year's soild waste discharge}}{\text{last year's soild waste discharge}} \times 100\%$$

(5) Rate of Household Wastes Hazard-free Treatment (%)

Index Explanation: Harmless domestic garbage treatment rate refers to the harmless treatment of industrial parks in the amount of domestic garbage as a percentage of the total amount of domestic garbage generated.

Calculation formula:

$$\text{Rate of Household Wastes Hazard} - \text{free Treatment} = \frac{\text{Household Wastes Hazard} - \text{free Treatment(ten thousand tons)}}{\text{Generated Household Wastes (ten thousand tons)}} \times 100\%$$

(6) Rate of Hazardous Wastes Treatment and Disposal (%)

Index Explanation: Hazardous waste refers to hazardous wastes included in the national inventory of hazardous wastes or hazardous wastes identified according to national standards for the identification and identification of hazardous wastes.

Disposal of hazardous waste refers to the disposal of hazardous waste generated in the park according to the relevant national laws, regulations and standards.

Calculation formula:

$$\text{Rate of Hazardous Wastes Treatment and Disposal} = \frac{\text{The Amount of Hazardous Wastes Treatment (t)}}{\text{The Amount of Hazardous Wastes (t)}} \times 100\%$$

(7) Rate of Sewage Treatment Plant Effluent Quality Compliance (%)

Index Explanation: Refers to the sewage treatment plant monthly (or year) effluent quality standards days / month (or year) normal operation days. The effluent quality standards are based on the project design standards approved in the preliminary design of the approved (or approved) project and the approval of the EIA report.

Calculation formula:

$$\text{Rate of Sewage Treatment Plant Effluent Quality Compliance} = \frac{\text{Daily or monthly water quality standards for the number of days (}d\text{)}}{\text{Daily or monthly running for the number of days (}d\text{)}}$$

(8) Average Regional Environmental Noise (dB)

Index Explanation: According to "Acoustic Environmental Quality Standard" GB3096-2008 acoustic environment functional area classification standards, TEDA should belong to the second category acoustic environment function area. Category 2 Acoustic Environment Function Zone refers to the commercial, financial, market or trade as the main function, or residential, commercial, industrial mixed, need to maintain quiet residential area. The noise limits of the Category 2 Acoustic Environment Function Zone are 60 dB during the day and 50 dB at night.

(9) Average Road Traffic Noise (dB)

Index Explanation: According to the Acoustic Environmental Functional Area Classification Standard of Acoustic Environmental Quality Standard (GB3096-2008), the Acoustic Functional Areas of Category 4 refer to areas within a certain distance on both sides of the traffic trunk line, and areas that need to be protected from traffic noise should have a serious impact on the surrounding environment, including Class 4a And 4b type two types. Category 4a is expressways, first-class highways, second-class highways, urban expressways, urban trunk roads, urban secondary roads, urban rail transit (ground section) and both sides of the inland waterway; Class 4a Acoustic Environment The noise limits for the functional area are 70 dB during the day and 55 dB at night.

Ecological Construction C_7:

(1) Coverage Rate of Regulated Area of Dust and Smoke (%)

Index Explanation: Refers to the percentage of the total area of built-up areas of urban areas built up by the area of dust control zones built in the urban built-up areas.

Calculation formula:

$$\text{Coverage Rate of Regulated Area of Dust and Smoke} = \frac{\text{Built control area of dust and smoke}}{\text{The total area of urban built area}} \times 100\%$$

(2) Rate of Secondary Air Quality Standard Compliance (%)

Index Explanation: Air quality 2nd standard compliance refers to the air quality reaches and better than two days accounted for a year's proportion.

Calculation formula:

$$\text{Rate of Secondary Air Quality Standard Compliance} = \frac{\text{Days of air quality reached and better than 2nd standard}}{365} \times 100\%$$

(3) Rate of Park Greenery Coverage(%)

Index Explanation: Refers to the total area of various types of green space in the park as a percentage of the total land area in the park.

Calculation formula:

$$\text{Rate of Park Greenery Coverage} = \frac{\text{The total area of green space}}{\text{The total area}} \times 100\%$$

(4) Satisfaction of the Public toward the Environment (%)

Index Explanation: Refers to the spot checks of residents of the park in the production, environmental protection and other aspects of the total number of people being spotted as a percentage of the total. The total number of spot checks shall not be less than one thousandth of the total number of permanent residents in the area where the park is located

Ecological Improvement Potentials C_8:

(1) Percentage of Environmental Protection in GDP (%)

Index Explanation: The ratio of environmental investment in total investment refers to the ratio of the total investment in environmental protection.

Calculation formula:

$$\text{Percentage of Environmental Protection in GDP} = \frac{\text{Environmental investment costs (ten thousand yuan)}}{\text{Total investment costs (ten thousand yuan)}} \times 100\%$$

(2) Percentage of Clean Energy in Total Energy (%)

Index Explanation: The percentage of clean energy refers to the percentage of clean energy used in the park which accounts for the total energy consumption in the park. Clean energy is energy that does not emit pollutants. It includes nuclear energy and renewable energy. Renewable energy refers to the renewable energy of raw materials, such as hydropower, wind power, solar energy, bio-energy (biogas), tidal energy.

Calculation formula:

$$\text{Percentage of Clean Energy in Total Energy} = \frac{\text{clean energy consumption}}{\text{total energy consumption}} \times 100\%$$

(3) Ratio of Public Transport Sharing (%)

Index Explanation: Public transport sharing rate referred to as bus sharing rate, refers to the choice of public transport (including regular bus and rail transit) travel style of urban residents travel ratio of the total amount of travel.

Calculation formula:

$$\text{Ratio of Public Transport Sharing} = \frac{\text{The total number of trips by public transport}}{\text{The total number of trips}} \times 100\%$$

Management Level C_9:

(1) Park Environmental Report Preparation

Index Explanation: Refers to the regular preparation of the park environmental report, usually a year.

The environmental report prepared shall include the assessment of the environmental quality of the park, the discharge of pollutants, the reduction of the use of resources and energy, the emission reduction of wastes, the monitoring and control measures for pollutants, the evaluation of their effects and the disposal of wastes.

(2) Completeness of Environmental Management System

Index Explanation: The degree of environmental management system improvement refers to the improvement and implementation of environmental monitoring and management systems and institutions in the park. The main environmental management systems under examination are the establishment of the IS014000 system, the establishment of cleaner production and contingency plans, on-line monitoring measures, and pollution control facilities in the park.

(3) Monitoring on Park Change

Index Explanation: The park's change monitoring capability includes on-line monitoring of flue gas in the park and on-line monitoring of key water sources.

(4) Eco-industrial Training

Index Explanation: In the eco-industrial park, eco-industrial policies and eco-industrial park theoretical knowledge training courses should be regularly held.

Infrastructure Supporting Capacity C_{10}:

(1) Completeness of Supporting Infrastructures

Index Explanation: The degree of completeness of infrastructure facilities refers to the degree of conformity required by economic development with the supporting infrastructure. Eco-industrial park infrastructure contains energy systems, water supply and drainage systems, transportation systems, communications systems, disaster prevention systems and other engineering facilities.

(2) Completeness of Information System

Index Explanation: Refers to the improvement of information system construction in the park. Whether the main assessment of whether to create a local area network;

Whether the Park Administrative Committee website, local area network or related Web site release pollutant emissions, solid waste generation, supply and demand and flow of information; whether in the park LAN has industry-leading information technology industry cleaner production (Including raw material selection, water conservation, energy saving, etc.) [43]. Which create 25% LAN, release of pollutants accounted for 25%, release of solid waste information accounted for 25%, providing leading industry, cleaner production technology information accounted for 25%.

(3) Percentage of Professionals in Environmental Administration Organizations (%)

Index Explanation: The ratio of professionals in environmental management agencies refers to the ratio of the number of staff with relevant specialties to the number of employees in the organization.

Employment C_{11}:

(1) Ratio of the Number of Tertiary Industry Employees (%)

Index Explanation: Tertiary industry practitioner ratio is the number of tertiary industries divided by the total number of employment.

(2) Ratio of Employment Added by Developing Circular Economy (%)

Index Explanation: Refers to the development of circular economy increased employment and the percentage of the total population of the region.

Happiness Index C_{12}:

(1) Engel Coefficient (%)

Index Explanation: The ratio of food consumption expenditure to total consumption expenditure is a general measure of living standards, quality of life, and living standards. According to the size of the Engel's Coefficient, the UN has a standard of living for all countries in the world. That is, the average Engel's coefficient of a country is more than 60% of poverty, 50-60% of it is food and clothing, 40-50% of well-being, 30% 40% are relatively affluent; 20% -30% are affluent; 20% are extremely affluent.

(2) Social Security Coverage (%)

Index Explanation: Refers to the ratio of the number of people participating in old-age care, medical treatment and unemployment insurance to the total number of people, indicating the coverage of the social security system.

3.3 Construction of Comprehensive Evaluation Index System of Enterprise Circular Economy

3.3.1 Design Principle

In order to ensure the scientific, practicality and accuracy of the circular economy index system of enterprises, the following principles should be followed in establishing the index system of evaluation:

(1) Comprehensive and scientific principles. Enterprise circular economy evaluation index system covers a wide range, can be comprehensive

And comprehensively reflect the interaction and harmonious development of various elements of economy, society, resources, environment, technology and management of the enterprise's circular economy development. Requirements of the concept of accurate indicators, connotation and denotation should be clear, the calculation method to be scientifically feasible.

(2) The principle of combining static indicator with dynamic indicator. The purpose of building an index system of circular economy of enterprises is not only to evaluate the development of circular economy of an enterprise, but more importantly, to analyze the potential and future trend of circular economy of an enterprise. Therefore, the evaluation index system should not only reflect the static index of the current scale and development level of the circular economy, but also have a dynamic index that comprehensively reflects the dynamic change characteristics and development trend of the circular economy system.

(3) Systematic and hierarchical principles. Enterprise recycling economy system is a complex large system, which consists of several subsystems. Therefore, the evaluation of enterprise recycling economy should be used different indexes at different levels. Therefore, establishing a hierarchy of comprehensive evaluation index system can create conditions for further factor analysis.

(4) The combination of qualitative indicators and quantitative indicators. The indicators of circular economy are quantified as much as possible. However, for some

indicators that are difficult to quantify and of great significance for research purposes, qualitative indicators can also be used to describe them. The combination of qualitative and quantitative evaluation can avoid the defects brought by relying solely on a certain method and improve the scientificity and objectivity of evaluation.

(5) Recycling economy principle. The core of circular economy is to reflect the application of the principle of circular economy and the application of the principle, so in the selection of circular economy to develop comprehensive evaluation indicators, we must give full consideration to the principle of "importance, to highlight the principle of" Indicators in the overall index system status and role.

3.3.2 Framework Determination

In general, the evaluation index system for circular economy of enterprises is divided into three levels: the target level, the guideline level and the index level.

Target level: To comprehensively express the overall capability of circular economy development of enterprises and reflect the overall status and development trend of circular economy development of enterprises.

Guidelines: The overall state of circular economy development of enterprises is broken down into economic benefits, resources and energy consumption, waste discharge, recycling and other aspects, each with different emphasis, reflecting the level of circular economy in the corresponding aspects of enterprise development.

Index layer: Measurable, comparable and available indexes and indexes to measure the quantitative performance, intensity performance or rate performance of circular economy in the enterprise are the most basic elements of the index system. The selection of indexes to follow the above principles, considering all aspects of corporate development designed.

3.3.3 Primary Selection and Screening of Evaluation Index

3.3.3.1 Evaluation Index Primary Selection

According to the primary indexes screening method, the candidate indexes of each criterion layer were summarized in Table 3.27. All alternative indexes were selected from a large number of relevant literatures (Han, W., 2009; He, W., 2006; Zhong et al., 2006; Guan, W.D., 2012; Zheng et al., 2008; Yang et al., 2012; Yu et al., 2010; Wu, J., 2009; Ou Yang, L.W., 2006).

Table 3.27 Primary Indexes of Enterprise Circular Economy Evaluation

Criteria Layers	**Indexes**
Economic Benefits C_1	Growth Rate of Sales RevenueM_{11}, Net Return on AssetsM_{12}, Return Rate on SalesM_{13}, Economic Output DensityM_{14}, Input-output RatioM_{15}, Growth Rate of Industrial Added ValueM_{16}, Economic Benefits from the Implementation of Circular EconomyM_{17}, Return Rate on Total AssetsM_{18}, Non-power Output Value RatioM_{19}
Resource & Energy Consumption C_2	Standard Unit Coal Consumption for Power GenerationM_{21}, Standard Unit Coal Consumption for Power SupplyM_{22}, Water Consumption for Unit ProductM_{23}, Energy Use Reduction RateM_{24}, Raw-materials Use Reduction RateM_{25}, Comprehensive Station Service Power Consumption RateM_{26}, Oil Consumption for Unit ProductM_{27}, Energy Utilization EfficiencyM_{28}, Annual Heat-to-electric RatioM_{29}
Waste Discharge C_3	Standard Discharge Rate of WastewaterM_{31}、Standard Discharge Rate of Exhaust GasM_{32}、Safe Disposal Rate of Hazardous WastesM_{33} 、 Rate of Environmental Noise Reaching StandardsM_{34}、Flue Dust Emission for Unit ProductM_{35}, Sulfur Dioxide Emission for Unit ProductM_{36}, Nitric Oxide Emission for Unit ProductM_{37}, Ash Residue Production for Unit ProductM_{38}, Wastewater Production for Unit ProductM_{39}
Recycle & Reuse C_4	Comprehensive Repeated Utilization Factor of Domestic SewageM_{41}, Comprehensive Repeated Utilization Factor of Industrial WastewaterM_{42}, Reuse Water Utilization RatioM_{43}, Comprehensive Utilization Factor of desulfurization gypsumM_{44}, Comprehensive Utilization Factor of Coal AshM_{45}, Comprehensive Utilization Factor of Bottom AshM_{46}, Comprehensive Utilization Factor of Exhaust HeatM_{47}
Environmental Protection Construction & Technological Innovation Capabilities C_5	Rate of Enterprise Environmental Protection InvestmentM_{51}, Environmental Protection Equipment ProportionM_{52}, Enterprise Eco-environmental Transformation PotentialsM_{53}, Innovation Input CapabilityM_{54}, Green-technology Implementation LevelM_{55}, Technological R&D CapabilityM_{56}, Ratio of Scientific and Technical PersonnelM_{57}
Enterprise Management & Social Benefits C_6	Enterprise Circular Economy Knowledge TrainingM_{61}, Enterprise Circular Economy Norms ConstructionM_{62}, Enterprise Information System ConstructionM_{63}, Management Awareness about Environmental ProtectionM_{64}, Employee Awareness about Environmental ProtectionM_{65}, Enterprise Brand Value and Social ImageM_{66}

3.3.3.2 Evaluation Index Screening

According to the results of the expert consultation survey (questionnaire template shown in APPENDIX 2), fill in the following tables with experts' opinions for screening the primary indexes.

(1) Index Screening of Economic Benefits

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.28.

Table 3.28 Overlapping analysis of C1 alternative indexes

	M11	M12	M13	M14	M15	M16	M17	M18
M11	1	0	2	0	0	2	0	2
M12	0	1	0	0	2	2	0	2
M13	2	0	1	0	0	2	0	0
M14	0	0	0	1	0	0	0	0
M15	0	2	0	0	1	0	0	2
M16	2	2	2	0	0	1	0	0
M17	0	0	0	0	0	0	1	0
M18	2	2	0	0	2	0	0	1
∑	7	7	5	1	5	7	1	7

As can be seen from the above table, the M14 and M17 indexes are better independent, and these two indexes are characteristic indexes of the circular economy of the enterprises. They are innovative and reserved. M13 and M15 index independence is not strong, give up. M11 and M18 index summation result is 7, the overlap of these two indexes is high. Considering the frequency of these two indexes appearing in relevant literature and expert's suggestion, keep M11 index and discard M18. Similarly, M12 and M16 overlap is high, keep M12, discard M16.

To sum up, according to the index screening and analysis, the indexes retained in the "economic benefit" criterion are: the growth rate of sales revenue M11, the return on net assets M12, the economic output density M14 and the economic benefits obtained from the implementation of circular economy 4 indexes.

(2) Index Screening of Resource & Energy Consumption

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.29.

Table 3.29 Overlapping analysis of C2 alternative indexes

	M21	M22	M23	M24	M25	M26	M27	M28	M29
M21	1	0	0	0	2	0	0	0	0
M22	0	1	0	2	0	0	0	0	0
M23	0	0	1	0	0	0	0	0	0
M24	0	2	0	1	0	0	0	0	0
M25	2	0	0	0	1	0	0	0	0
M26	0	0	0	0	0	1	0	0	0
M27	0	0	0	0	0	0	1	0	0
M28	0	0	0	0	0	0	0	1	0
M29	0	0	0	0	0	0	0	0	1
∑	3	3	1	3	3	1	1	1	1

As can be seen from the above table, M23, M26, M27, M28 and M29 indexes independence is better, and the five indexes as a necessary index of resource consumption in recycling economy enterprises, the measure of enterprise resource consumption level is very Great meaning, to be retained. M21 and M25 two indexes overlap, from the perspective of business development in the long run, when the production of certain or increased, the amount of raw materials used by enterprises will not have been reduced, but will be maintained at a stable level, so "to reduce Rate "is not suitable as a long-term consideration of indexes; unit output value consumption of this index has a certain rationality and practicality, taking into account the two indexes appear in the relevant literature frequency and expert advice to retain M21 Indexes, discard M25. Similarly, to measure the energy consumption of M22 and M24 indexes, keep M22, give up M24.

To sum up, according to the index selection and analysis, the indexes retained in the "Resource and Energy Consumption" guideline are as follows: raw material consumption of Million Yuan output value M21, comprehensive energy consumption of Million Yuan output value M22, fresh water consumption of Million Yuan output value M23, Corporate clean energy utilization rate M26, recycled material utilization rate M27, energy utilization rate M28, and utilization rate of raw material M29.

(3) Index Screening of Waste Discharge

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.30.

Table 3.30 Overlapping analysis of C3 alternative indexes

	M31	M32	M33	M34	M35	M36	M37	M38	M39
M31	1	0	0	0	0	0	0	0	0
M32	0	1	0	0	0	0	0	0	0
M33	0	0	1	0	0	0	0	0	0
M34	0	0	0	1	2	0	0	0	0
M35	0	0	0	2	1	0	0	0	0
M36	0	0	0	0	0	1	0	0	0
M37	0	0	0	0	0	0	1	0	0
M38	0	0	0	0	0	0	0	1	0
M39	0	0	0	0	0	0	0	0	1
∑	1	1	1	3	3	1	1	1	1

As can be seen from the above table, in addition to the M34 and M35, the other indexes independence is better, and as a necessary index of the waste discharge in the enterprise recycling economy, it is of great significance to measure the discharge and processing capacity of the enterprise waste, Be retained. M34 and M35 two indexes overlap, from the perspective of business development in the long run, with the improvement of the production process, the amount of wastewater may be slightly decreased, but will not always reduce the trend, especially when the output is large When the increase is made, the reduction rate of wastewater discharge will become very small, so the "reduction rate" is not suitable as a long-term index; and the index of wastewater discharge per unit output is reasonable and practical. At the same time, considering the frequency of occurrence of these two indexes in the relevant literature and expert advice, the M35 index is retained and M34 discarded.

To sum up, according to the index screening and analysis, the indexes retained in the "Waste Discharge" guideline are as follows: wastewater discharge rate M31, discharge gas discharge rate M32, discharge rate of hazardous waste M33, waste water discharge M10, Million yuan output value of COD emissions, Million yuan output value of emissions, Million yuan output value of sulfur dioxide emissions, Million yuan output value of solid waste emissions M39 a total of eight indexes.

(4) Index Screening of Recycle & Reuse

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.31.

Table 3.31 Overlapping analysis of C4 alternative indexes

	M41	M42	M43	M44	M45	M46
M41	1	0	0	0	0	0
M42	0	1	2	0	0	0
M43	0	2	1	0	0	0
M44	0	0	0	1	0	0
M45	0	0	0	0	1	0
M46	0	0	0	0	0	1
∑	1	3	3	1	1	1

As can be seen from the above table, in addition to the M42 and M43, the other indexes of independence, and as an important index of recycling companies in the recycling economy, the measure of business resources and energy recycling capacity and level of Great meaning, to be retained. M42 and M43 two indexes overlap, according to the frequency of these two indexes appear in the literature and expert advice, that in the business practice, "Integrated Wastewater Reuse Ratio" than the "water reuse rate" is more applicable, The wastewater produced by the enterprise can be used as water for irrigation on the ground of the factory with low water quality requirements after treatment. It is not necessary to recycle it to the standard of reclaimed water. Therefore, M42 should be reserved and M43 should be discarded.

To sum up, according to indexes selection and analysis, the indexes retained in the "recycling" guidelines are as follows: the utilization rate of intermediate byproducts M41, the comprehensive wastewater reuse M42, the comprehensive utilization rate of solid waste M44, the comprehensive utilization ratio of residual heat M45 , Packaging material recycling rate M46 a total of five indexes.

(5) Index Screening of Environmental Protection Construction & Technological Innovation Capabilities

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.32.

Table 3.32 Overlapping analysis of C5 alternative indexes

	M51	M52	M53	M54	M55	M56	M57
M51	1	3	0	0	0	0	0
M52	3	1	0	0	0	0	0
M53	0	0	1	0	2	0	0
M54	0	0	0	1	0	0	0
M55	0	0	2	0	1	0	0
M56	0	0	0	0	0	1	0
M57	0	0	0	0	0	0	1
∑	4	4	3	1	3	1	1

As can be seen from the above table, the indexes M54, M56 and M57 have better independence and are of great significance as a necessary index of environmental protection construction and technological innovation capability in the circular economy of enterprises. M51 and M52 two indexes overlap, M52 indexes included in the M51, M51 indexes on the ratio of corporate environmental investment covers more comprehensive, it retains M51, discard M52. At the same time, indexes M53 and M55 are overlapping. According to the frequency of these two indexes appeared in relevant literature and the suggestions from experts, it is considered that "potential of ecological environment reform" is more suitable than "level of green technology implementation" in enterprise practice, so M53 Indexes, discarded M55.

To sum up, according to the index screening and analysis, the indexes retained in the guideline layer of "environmental protection construction and technological innovation ability" include M51 environmental investment rate, M53 ecological transformation potential, M54 innovation investment capability, M56 technology research and development capability, The ratio of science and technology M57 a total of five indexes.

(6) Index Screening of Enterprise Management & Social Benefits

The overlapping of the primary indexes were analyzed, and the value of relationship between the indexes were filled in the relationship table, shown in Table 3.33.

Table 3.33 Overlapping analysis of C6 alternative indexes

	M61	M62	M63	M64	M65	M66	M67
M61	1	0	0	0	0	0	0
M62	0	1	0	0	0	0	0
M63	0	0	1	0	0	0	0
M64	0	0	0	1	3	0	0
M65	0	0	0	3	1	0	0
M66	0	0	0	0	0	1	2
M67	0	0	0	0	0	2	1
∑	1	1	1	4	4	3	3

As can be seen from the above table, the indexes M61, M62 and M63 have better independence and are of great significance to be retained as necessary indexes for enterprise management and social benefits in circular economy of enterprises. M64 and M65 two indexes overlap, the index M64 is included in the M65, and corporate employees environmental awareness than the management of environmental awareness is more important, only the general staff increased awareness of environmental protection, to ensure that in all aspects of the production line Achieve energy-saving emission reduction, so keep M65, give up M64.

At the same time, the indexes M66 and M67 are overlapping. Based on the frequency of these two indexes in the relevant literature and the suggestions from experts, it is considered that "corporate brand value and social image" are more important than "corporate honor" M66 indexes, give up M67.

3.2.4 Comprehensive Evaluation Index System of Enterprise Circular Economy

According to the screening method, the overlapping indexes in each layer were deleted by screening from primary index system. An enterprise circular economy evaluation index system was determined containing 6 criteria layers and 34 index layers (shown in Table 3.34).

Table 3.34 Enterprise Circular Economy Evaluation Index System

	Indexes	Unit
Economic Benefits C1	Growth Rate of Sales Revenue M1	%
	Net Return on Assets M2	%
	Economic Output Density M3	ten thousand yuan/hectare
	Economic Benefits from the Implementation of Circular Economy M4	ten thousand yuan/year
Resource & Energy Consumption C2	Raw Material Consumption Per Ten Thousand Yuan Output Value M5	t/ten thousand yuan
	Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value M6	t-standard coal/ ten thousand yuan
	Fresh Water Consumption Per Ten Thousand Yuan Output Value M7	m^3/ten thousand yuan
	Enterprise Clean Energy Utilization Rate M8	%
	Renewable Material Utilization Rate M9	%
	Energy Utilization Efficiency M10	%
	Raw Material Utilization Rate M11	%
Waste Discharge C3	Standard Discharge Rate of Wastewater M12	%
	Standard Discharge Rate of Exhaust Gas M13	%
	Safe Disposal Rate of Hazardous Wastes M14	%
	Wastewater Discharge Per Ten Thousand Yuan Output Value M15	t/ten thousand yuan
	COD Emission Per Ten Thousand Yuan Output Value M16	kg/ten thousand yuan
	Exhaust Emissions Per Ten Thousand Yuan Output Value M17	m^3/ten thousand yuan
	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value M18	m^3/ten thousand yuan
	Solid Waste Emission Per Ten Thousand Yuan Output Value M19	t/ten thousand yuan
Recycle & Reuse C4	Intermediate By-products Utilization Rate M20	%
	Wastewater Comprehensive Utilization Rate M21	%
	Solid Waste Comprehensive Utilization Rate M22	%
	Waste Heat Utilization Rate M23	%
	Packaging Material Recycling Rate M24	%
Environmental Protection Construction & Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment M25	%
	Environmental Protection Equipment Proportion M26	%
	Innovation Input Capability M27	%
	Technological R&D Capability M28	unit/hundred people
	Ratioof Scientific and Technical Personnel M29	%
Enterprise Management & Social Benefits C6	Enterprise Circular Economy Knowledge Training M30	%
	Enterprise Circular Economy Norms Construction M31	—
	Enterprise Information System Construction M32	—
	Employee Awareness about Environmental Protection M33	—
	Enterprise Brand Value and Social Image M34	—

3.2.5 Evaluation Index Significance

Economic Strength C_1:

(1) Growth Rate of Sales Revenue (%)

Index Explanation: To reflect the company's operating conditions, market share and business development potential.

Calculation formula:

$$\text{Growth Rate of Sales Revenue} = \frac{\text{Increase in Sales Revenue}}{\text{Sales Revenue}} \times 100\%$$

(2) Net Return on Assets (%)

Index Explanation: It is the core index for evaluating the operating efficiency of an enterprise. It reflects the ability of investors to invest their own capital to obtain net income and reflects the relationship between investment and remuneration.

Calculation formula:

$$\text{Net Return on Assets} = \frac{\text{Net Profit}}{\text{Average Net Assets}} \times 100\%$$

(3) Economic Output Density (ten thousand yuan/hectare)

Index Explanation: This index is used to measure the economic efficiency of enterprises and land use efficiency.

Calculation formula:

$$\text{Economic Output Density} = \frac{\text{Gross Output Value (ten thousand yuan)}}{\text{Land Area (hectare)}}$$

(4) Economic Benefits from the Implementation of Circular Economy (ten thousand yuan/year)

Index Explanation: Enterprises in the implementation of circular economy, because of resource conservation, waste recycling, resulting in lower production costs and access to additional economic benefits, therefore, the establishment of "recycling economy to obtain the economic benefits of indexes" in the evaluation of the economic benefits of enterprises indispensable.

Resource & Energy Consumption C_2:

(1) Raw Material Consumption Per Ten Thousand Yuan Output Value (t/ten thousand yuan)

Index Explanation: It is s an index for measure enterprise's reduction of input into the production, and the index reflects the raw materials cost caused by consumption per 10,000 yuan. To illustrates the enterprise resource consumption in the production process.

Calculation formula:

$$\text{Raw Material Consumption Per Ten Thousand Yuan Output Value} = \frac{\text{Raw Material Input (ton)}}{\text{Gross output value(ten thousand yuan)}}$$

(2) Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value (t-standard coal/ ten thousand yuan)

Index Explanation: This is an index reflecting the extent to which an enterprise uses less energy in its production.

Calculation formula:

$$\text{Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value} = \frac{\text{Comprehensive Energy Consumption(t - standard coal)}}{\text{Gross output value(ten thousand yuan)}}$$

(3) Fresh Water Consumption Per Ten Thousand Yuan Output Value (m^3/ten thousand yuan)

Index Explanation: This is an index that reflects the degree of water resources utilization in an enterprise. Fresh water here does not include tap water for reuse and reuse.

Calculation formula:

$$\text{Fresh Water Consumption Per Ten Thousand Yuan Output Value} = \frac{\text{Total Consumption of Fresh Water } (m^3)}{\text{Gross output value(ten thousand yuan)}}$$

(4) Enterprise Clean Energy Utilization Rate (%)

Index Explanation: Clean energy refers to the use of renewable energy that is as low as possible (zero) and low-pollution as possible in the production process, which is harmless or harmless to people and the environment, and to the extent possible. It includes low-pollution renewable energy, fossil fuels and fossil fuels that have been treated with clean energy technologies.

Calculation formula:

$$\text{Enterprise Clean Energy Utilization Rate} = \frac{\text{Clean Energy Consumption}}{\text{Total Energy Consumption}} \times 100\%$$

(5) Renewable Material Utilization Rate (%)

Index Explanation: It reflects the ability of a company to reduce the use of materials, but also indirectly reflects the reduction of raw materials put into use.

Calculation formula:

$$\text{Renewable Material Utilization Rate} = \frac{\text{Renewable Materials Input}}{\text{Total Raw Materials Input}} \times 100\%$$

(6) Energy Utilization Efficiency (%)

Index Explanation: It is a concentrated reflection of the degree of efficient use of various energy sources consumed by enterprises

Calculation formula:

$$\text{Energy Utilization Efficiency} = \frac{\text{Effective Use of Energy}}{\text{Total Energy Consumption}} \times 100\%$$

(7) Raw Material Utilization Rate (%)

Index Explanation: It refers to the production process of a certain number of raw materials produced by the number of products, or the formation of product entities, the amount of raw materials accounted for the ratioof input. It is an index of the degree of utilization of raw materials. The higher the degree of utilization, the same amount of raw materials can be produced to produce more products, or produce the same amount of product can consume less raw materials. It is a comprehensive reflection of enterprise production technology and management level.

Calculation formula:

$$\text{Raw Material Utilization Rate} = \frac{\text{The Total Amount of Raw Materials for Products}}{\text{The Total Amount of Raw Materials Input}} \times 100\%$$

Waste Discharge C_3:

(1) Standard Discharge Rate of Wastewater (%)

Index Explanation: In the discharge process of the wastewater generated in producing after treatment, it is a ratio of the discharge up standard and total discharge.

Calculation formula:

$$\text{Standard Discharge Rate of Wastewater} = \frac{\text{The Standard Discharge of Wastewater}}{\text{The Total Discharge of Wastewater}} \times 100\%$$

(2) Standard Discharge Rate of Exhaust Gas (%)

Index Explanation: In the discharge process of the exhaust gas generated in producing after treatment, it is a ratio of the discharge up standard and total discharge.

Calculation formula:

$$\text{Standard Discharge Rate of Exhaust Gas} = \frac{\text{The Standard Discharge of Exhaust Gas}}{\text{The Total Discharge of Exhaust Gas}} \times 100\%$$

(3) Safe Disposal Rate of Hazardous Wastes (%)

Index Explanation: Among the hazardous wastes generated in the production, the ratio of wastes that have been disposed of by the corresponding treatment processes and eventually disposed of safely accounts for the total amount of hazardous wastes generated.

Calculation formula:

$$\text{Safe Disposal Rate of Hazardous Wastes} = \frac{\text{Safe Disposal of Hazardous Wastes}}{\text{The Total Hazardous Wastes}} \times 100\%$$

(4) Wastewater Discharge Per Ten Thousand Yuan Output Value (t/ten thousand yuan)

Index Explanation: The ratio of the total amount of wastewater discharged during the production process to the total output value of enterprises reflects the indexes of pollutant discharge of the enterprises and can be used for the control of pollutant reduction.

Calculation formula:

$$\text{Wastewater Discharge Per Ten Thousand Yuan Output Value} = \frac{\text{Total Wastewater Discharge(ton)}}{\text{Gross Output Value(ten thousand yuan)}}$$

(5) COD Emission Per Ten Thousand Yuan Output Value (kg/ten thousand yuan)

Index Explanation: The ratio of the total amount of COD discharged during the production of the enterprise to the total output value of the enterprise reflects the emission index of organic pollutants in the waste water discharged by enterprises and can be used for the reduction control of organic pollutants.

Calculation formula:

$$\text{COD Emission Per Ten Thousand Yuan Output Value} = \frac{\text{Total COD Emission (kg)}}{\text{Gross Output Value(ten thousand yuan)}}$$

(6) Exhaust Gas Emissions Per Ten Thousand Yuan Output Value (m^3/ten thousand yuan)

Index Explanation: The ratio of the total amount of exhaust gas discharged during the production of a company to the total output value of an enterprise reflects the emission of air pollutants from an enterprise and can be used to control the reduction of air pollutants.

Calculation formula:

$$\text{Exhaust Gas Emission Per Ten Thousand Yuan Output Value} = \frac{\text{Total Exhaust Gas Emission } (m^3)}{\text{Gross Output Value(ten thousand yuan)}}$$

(7) Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value (m^3/ten thousand yuan)

Index Explanation: The ratio of the total amount of sulfur dioxide emitted to the total output value of enterprises in the production process reflects the emission of sulfur dioxide in the air pollutants of enterprises and can be used for the reduction control of atmospheric sulfur pollutants.

Calculation formula:

$$\text{Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value} = \frac{\text{Total Sulfur Dioxide Emission}(m^3)}{\text{Gross Output Value(ten thousand yuan)}}$$

(8) Solid Waste Emission Per Ten Thousand Yuan Output Value (t/ten thousand yuan)

Index Explanation: The ratio of the total amount of solid waste generated during the production of the enterprise to the total output value of the enterprise reflects the discharge of solid wastes from the enterprises and can be used for the control of the reduction of solid wastes.

Calculation formula:

$$\text{Solid Waste Emission Per Ten Thousand Yuan Output Value} = \frac{\text{Total Solid Waste Emission}(t)}{\text{Gross Output Value(ten thousand yuan)}}$$

Recycle & Reuse C_4:

(1) Intermediate By-products Utilization Rate (%)

Index Explanation: It is used to measure a company's recycling capacity of raw materials input.

Calculation formula:

$$\text{Intermediate By-products Utilization Rate} = \frac{\text{Total By-product Utilization}}{\text{Total Raw Materials Input}} \times 100\%$$

(2) Wastewater Comprehensive Utilization Rate (%)

Index Explanation: The index reflects the degree of corporate use of water resources reduction. Also indirectly reflects the degree of business transformation of environmental pollution and environmental protection efforts.

Calculation formula:

$$\text{Wastewater Comprehensive Utilization Rate} = \frac{\text{Reuse Water after Treatment}}{\text{The Total Wastewater in Production Process}} \times 100\%$$

(3) Solid Waste Comprehensive Utilization Rate (%)

Index Explanation: It reflects the level of comprehensive utilization of solid waste generated by the enterprise during the production process and indirectly reflects the degree of quantification of solid waste generated by the enterprise

Calculation formula:

$$\text{Solid Waste Comprehensive Utilization Rate} = \frac{\text{Solid Waste Comprehensive Utilization}}{\text{Solid Waste Output}} \times 100\%$$

(4) Waste Heat Utilization Rate (%)

Index Explanation: It is the ratio of waste heat recovered by the system to the corresponding supply energy in the production process of an enterprise. This index can be used to evaluate the degree of waste heat recovery and utilization, reflecting the magnitude of energy saving, but also determine the level of waste heat resources criteria.

Calculation formula:

$$\text{Waste Heat Utilization Rate} = \frac{\text{Recycling of Waste Heat}}{\text{The Total Energy Supplied}} \times 100\%$$

(5) Packaging Material Recycling Rate (%)

Index Explanation: It reflects the actual recycling of packaging that can be recycled by the business. Improve the recycling of packaging materials, reflecting the circular economy reduction, reuse, recycling of resources is the circular economy to business requirements.

Calculation formula:

$$\text{Packaging Material Recycling Rate} = \frac{\text{The Amount of Recycled Packaging Material}}{\text{The Amount of Packaging Material}} \times 100\%$$

Environmental Protection Construction & Technological Innovation Capabilities C_5:

(1) Rate of Enterprise Environmental Protection Investment (%)

Index Explanation: It reflects the intensity of corporate environmental investment is the contribution of enterprises to protect the environment.

Calculation formula:

$$\text{Rate of Enterprise Environmental Protection Investment} = \frac{\text{Enterprise Environmental Protection Investment}}{\text{Enterprise Added Value}} \times 100\%$$

(2) Environmental Protection Equipment Ratio(%)

Index Explanation: It reflects the potential of enterprises to invest in environmental protection facilities, that is, the ratioof environmental protection investment in fixed assets investment

Calculation formula:

$$\text{Environmental Protection Equipment Proportion} = \frac{\text{Total Investment in Environmental Protection}}{\text{Total Investment in Fixed Assets}} \times 100\%$$

(3) Innovation Input Capability (%)

Index Explanation: It is used to measure the continuous innovation of the business.

Calculation formula:

$$\text{Innovation Input Capability} = \frac{\text{Technological R \& D investment}}{\text{Total sales}} \times 100\%$$

(4) Technological R&D Capability (unit/hundred people)

Index Explanation: It is used to measure the degree of market-oriented innovation in business. Technology R&D capabilities through high-tech enterprises can achieve development and resource conservation.

Calculation formula:

$$\text{Technological R \& D Capability} = \frac{\text{The Amount of Patents} (-)}{\text{Number of Employees(hundred people)}}$$

(5) Ratio of Scientific and Technical Personnel (%)

Index Explanation: It is used to measure the technology soft power, and to reflect the talent structure and technological innovation potential.

Calculation formula:

$$\text{Proportion of Scientific and Technical Personnel} = \frac{\text{Number of scientific and technical personnel (hundred people)}}{\text{Number of Employees (hundred people)}} \times 100\%$$

Enterprise Management & Social Benefits C_6:

(1) Enterprise Circular Economy Knowledge Training (%)

Index Explanation: Knowledge of circular economy training is the first step in the implementation of circular economy development. The implementation of circular economy knowledge training directly affects the level of awareness of employees of circular economy and the circular economy agree with the extent and practice of the rules and regulations.

Calculation formula:

$$\text{Enterprise Circular Economy Knowledge Training} = \frac{\text{Number of Employees Trained in Knowledge of Circular Economy}}{\text{Number of Employees}} \times 100\%$$

(2) Enterprise Circular Economy Norms Construction (-)

Index Explanation: The construction of circular economy rules and regulations of enterprises is a concrete manifestation of the thought and development model of circular economy development. It enables all kinds of work to be followed and becomes a powerful guarantee for enterprises to implement the development model of circular economy. Sound rules and regulations have a direct impact on the successful implementation of this model.

(3) Enterprise Information System Construction (-)

Index Explanation: Information system construction is an important symbol of the level of development of circular economy. The smooth and rapid flow of information can guide the flow of material and energy to maximize the efficiency of the direction of development, making the eco-economic system coordinated operation.

(4) Employee Awareness about Environmental Protection (-)

Index Explanation: For the implementation of circular economy enterprises, staff awareness of environmental protection is very important. Through training, lectures and corporate culture and other means of shaping the environment, so that staff aware of the implementation of circular economy and cleaner production, saving resources and energy resources, which can take the initiative to eliminate waste, save energy, but also from the perspective of the interests of enterprises , Put forward rational proposals related to environmental protection.

(5) Enterprise Brand Value and Social Image (-)

Index Explanation: Brand value is the most central part of the brand management elements, but also an important symbol of brand differentiation from similar competitive brands. Recycling economy can help nurture and shape the industry and corporate brand image and value, because the majority of society awareness of the strengthening of ecological and environmental protection. The public image of an enterprise is an important factor that affects the sustainable development of an enterprise. It is also an acknowledgment of an enterprise in the society. As the implementation of circular economy in enterprises requires cleaner production and efficient use of resources, which will benefit the general public and will inevitably affect the public's understanding of the corporate image.

4. Comprehensive Evaluation Model of Eco-Industrial Parks Circular Economy

4.1 Determination of Evaluation Criteria and Index Weight

4.1.1 Evaluation Criteria Determination

After the target screening is completed, the evaluation criteria (ideal value) of the coordinated development of the eco-industrial park and the level of comprehensive development should be determined, that is, the maximum value (positive, effective, very large) and the minimum, Cost / loss, minima).

For the eco-industrial park, the ideal value of the comprehensive evaluation should be based on the characteristics of the park type and the "3R" principle of recycling economy. Based on the actual conditions, follow the "Comprehensive eco-industrial park standards" issued by the Ministry of Environmental Protection (HJ274-2009 (HJ274-2009) "," Industry Ecology Industrial Park Standard (Trial) "(HJ / T273-2006), and" Ventilation Industry Ecology Industrial Park Standard (Trial) "," HJ / T275-2006); and the industry technical standards formulated by the relevant industries; the optimal values of the domestic and international industries as revealed by the survey data of the State Environmental Protection Administration, the Circular Economy Statistical Yearbook and the government departments, etc., so as to rationally design and evaluate the ideal values.

4.1.2 Index Weight Determination

In the process of this study, we judge the value of *bij* by evaluating the importance of the evaluation indexes at all levels by consulting the relevant experts in circular economy, the cleaner production departments in key industries, financial experts and so on. The criteria for evaluation include six indexes: economic development (B1), resource utilization (B2), environmental protection (B3), ecological civilization (B4), park management (B5) and social progress (B6) The following judgment matrix is established to obtain the eigenvector corresponding to the largest eigenvalue and normalized to obtain the weight vector of the evaluation index of the criterion layer.

In this paper, questionnaire method and expert consultation method are used to screen primary indexes and determine the index weights, the questionnaires shown in Appendix 1- Appendix 8.

4.1.3 Survey Methodology and Outline

The questionnaire survey was conducted from Feb. 5, 2015 to Sept. 3, 2015. During this period, six rounds of investigations were carried out. Questionnaires are specially designed for this research, and 10 sets are returned each round, with the effective returning rate of 100%.

The specific content of each round is as follows:

(1) Screening primary index and determining index weight of eco-industrial parks circular economy;

(2) Screening primary index and determining index weight of enterprise circular economy;

(3) Determining index weigh of power enterprise circular economy;

(4) Determining index weigh of steel enterprise circular economy;

(5) Determining index weigh of coal enterprise circular economy;

(6) Determining index weigh of papermaking enterprise circular economy.

Participants in the questionnaire included policymakers, researchers, engineers, and enterprise managers.

(1) It gives a mark to each index of criterion layer of circular economy through the questionnaire and form visited.

(2) According to the statistics results of criterion layer, the weight coefficient is determined by subjective weighting method by two leading experts of circular economy.

(3) Gets the weight of each index of criterion layer by AHP.

(4) Similarly, it gives a mark to each index of index layer of circular economy through the questionnaire and form visited, gets the weight of each index of index layer by AHP.

4.1.4 Survey Results

The basic information of respondents is shown in Table 4.1, Table 4.2.

Table 4.1 Outline of the Survey

Period covered	Feb. 5, 2015 - Sept. 3, 2015
Area	Tianjin, Beijing of China
Recovery method	Visiting detention method
Survey number (people)	10, 6 rounds
Recovery rate	100%

Table 4.2 Attribute of Samples

Attribute		**Number of people**	**Attribute**		**Number of people**
Sex	Men	8	Profession	Researcher	1
	Women	2		Professor	4
Education	Undergraduate	2		Manager	4
	Master	2		Civil servant	1
	Doctor	6	Years of service	10	1
Age	30	1		20	1
	40	3		30	5
	50	5		40	3
	More than 60	1		More than 50	1

The survey respondent results are shown in Table 4.3.

Table 4.3 Experts' score results of eco-industrial parks' index weight determination

Criterion Layer B	Average Score	State Layer C	Average Score	Variable Layer M	Average Score
Economic Development B1	8.8	Economic Strength, C1	5.7	Per-capital Industrial Added Value (ten thousand yuan/capital) M1↑	3.0
				GDP Average Annual Growth Rate (%) M2↑	4.3
				Percentage of the Added Value of Tertiary Industry in GDP (%) M3↑	5.1
				Economic Output Density (100 Million yuan/sq.km.) M4↑	6.7
				Rate of Energy Output (10 Thousand yuan/tce) M5↑	8.3
				Rate of Water Resources Output (10 Thousand yuan/m^3) M6↑	2.5
		Economic Development Potentials C2	8.5	Percentage of Scientific Research Input in GDP (%)M7↑	8.6
				Percentage of High-tech Industry Output in Total Industrial Output Value (%) M8↑	8.2
				Enterprises Correlation M9↑	7.1
				Waste Chain Completeness M10↑	5.0
				Substitutability of Raw Materials Source M11↑	4.5
Resource Utilization B2	6.7	Resource Consumption C3	7.9	Comprehensive Energy Consumption per Unit of Industrial Added Value (tce/10 Thousand yuan)M12↓	7.5
				Fresh Water Consumption per Unit of Industrial Added Value (m^3/10 Thousand yuan) M13↓	6.1
				Comprehensive Energy Consumption Elasticity Coefficient M14↓	6.5
				Fresh Water Consumption Elasticity Coefficient M15↓	4.0
		Recycling Degree C4	5.1	Repetitiveness of Industrial Water (%) M16↑	3.5
				Comprehensive Utilization Ratio of Industrial Solid Wastes (%) M17↑	7.8
Environmental Protection B3	7.4	Sewage Discharge Intensity C5	8.2	Wastewater Production per Unit of Industrial Added Value (t/10 Thousand yuan) M18↓	7.1
				Solid Waste Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M19↓	4.9
				COD Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M20↓	6.0
				SO_2 Emission per Unit of Industrial Added Value (kg/10 Thousand yuan) M21↓	2.8
				COD Emission Elasticity Coefficient M22↓	2.5
				SO_2 Emission Elasticity Coefficient M23↓	2.5

(Continued)

Criterion Layer B	Average Score	State Layer C	Average Score	Variable Layer C	Average Score
Environmental Protection B3	7.4	Pollution Control C6	5.7	Rate of Industrial Wastewater Discharge Compliance (%) M24↑	8.3
				Rate of Industrial Wastewater Discharge Reduction (%) M25↑	4.5
				Rate of Main Air Pollutants Emission Compliance (%)M26↑	8.4
				Rate of Industrial Solid Wastes Discharge Reduction (%) M27↑	4.3
				Rate of Household Wastes Hazard-free Treatment (%) M28↑	8.5
				Rate of Hazardous Wastes Treatment and Disposal (%)M29↑	8.0
				Rate of Sewage Treatment Plant Effluent Quality Compliance (%) M30↑	8.0
				Average Regional Environmental Noise (db) M31↓	5.5
				Average Road Traffic Noise (db) M32↓	5.3
Eco-friendly B4	7.1	Ecological Construction C7	5.1	Coverage Rate of Regulated Area of Dust and Smoke (%) M33↑	7.7
				Rate of Secondary Air Quality Standard Compliance (%) M34↑	8.5
				Rate of Park Greenery Coverage(%) M35↑	6.8
				Satisfaction of the Public toward the Environment (%) M36↑	6.0
		Ecological Improvement Potentials C8	8.1	Percentage of Environmental Protection in GDP (%) M37↑	8.3
				Percentage of Clean Energy in Total Energy (%) M38↑	5.8
				Ratio of Public Transport Sharing (%) M39↑	4.3
Park Administration B5	5.5	Management Level C9	4.1	Park Environmental Report Preparation M40↑	3.3
				Completeness of Environmental Management System M41↑	8.8
				Monitoring on Park Change M42↑	6.5
				Eco-industrial Training M43↑	5.0
		Infrastructure Supporting Capacity C10	7.3	Completeness of Supporting InfrastructuresM44↑	8.2
				Completeness of Information System M45↑	6.2
				Percentage of Professionals in Environmental Administration Organizations (%) M46↑	6.8
Social Progress B6	4.0	Employment C11	7.9	Ratio of the Number of Tertiary Industry Employees (%) M47↑	4.2
				Ratio of Employment Added by Developing Circular Economy (%) M48↑	7.6
		Happiness Index C12	5.8	Engel Coefficient (%) M49↓	8.2
				Social Security Coverage (%) M50↑	4.5

The calculation method described in chapter 2.2.2.3.

$$M_1 = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{1j} = 1 \times 3 \times 3 \times 4 \times 5 \times 6 = 1080$$

$$M_2 = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{2j} = 1/3 \times 1 \times 1 \times 3 \times 4 \times 5 = 20$$

$$M_3 = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{3j} = 1/3 \times 1 \times 1 \times 3 \times 4 \times 5 = 20$$

$$M_4 = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{4j} = 1/4 \times 1/3 \times 1/3 \times 1 \times 3 \times 4 = 1/3$$

$$M_{51} = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{5j} = 1/5 \times 1/4 \times 1/4 \times 1/3 \times 1 \times 3 = 1/80$$

$$M_6 = \prod_{j=1}^{n} a_{ij} = \prod_{j=1}^{6} a_{6j} = 1/6 \times 1/5 \times 1/5 \times 1/4 \times 1/3 \times 1 = 1/1800$$

Then,

$$\overline{W_1} = \sqrt[6]{M_1} = \sqrt[6]{1080} = 3.2031$$

$$\overline{W_2} = \sqrt[6]{M_2} = \sqrt[6]{20} = 1.6475$$

$$\overline{W_3} = \sqrt[6]{M_3} = \sqrt[6]{20} = 1.6475$$

$$\overline{W_4} = \sqrt[6]{M_4} = \sqrt[6]{1/3} = 0.8327$$

$$\overline{W_5} = \sqrt[6]{M_5} = \sqrt[6]{1/80} = 0.4817$$

$$\overline{W_6} = \sqrt[6]{M_6} = \sqrt[6]{1/1800} = 0.2867$$

and,

$$\sum_{j=1}^{6} \overline{W_J} = 3.2031 + 1.6475 + 1.6475 + 0.8327 + 0.4817 + 0.2867 = 8.0992$$

$$W_1 = \frac{\overline{W_1}}{\sum_{j=1}^{6} \overline{W_J}} = \frac{3.2031}{8.0992} = 0.3994$$

$$W_2 = \frac{\overline{W_2}}{\sum_{j=1}^{6} \overline{W_J}} = \frac{1.6475}{8.0992} = 0.1998$$

$$\mathrm{W}_3 = \frac{\overline{\mathrm{W}_3}}{\sum_{j=1}^{6}\overline{\mathrm{W}_j}} = \frac{1.6475}{8.0992} = 0.1998$$

$$\mathrm{W}_4 = \frac{\overline{\mathrm{W}_4}}{\sum_{j=1}^{6}\overline{\mathrm{W}_j}} = \frac{0.8327}{8.0992} = 0.1045$$

$$\mathrm{W}_5 = \frac{\overline{\mathrm{W}_5}}{\sum_{j=1}^{6}\overline{\mathrm{W}_j}} = \frac{0.4817}{8.0992} = 0.0604$$

$$\mathrm{W}_6 = \frac{\overline{\mathrm{W}_6}}{\sum_{j=1}^{6}\overline{\mathrm{W}_j}} = \frac{0.2867}{8.0992} = 0.0361$$

and,

$$\frac{(AW)_1}{W_1} = (1 \times 0.3994 + 3 \times 0.1998 + 3 \times 0.1998 + 4 \times 0.1045 + 5 \times 0.0604 + 6 \times 0.0361)/0.3994 = 6.4151$$

$$\frac{(AW)_2}{W_2} = (1/3 \times 0.3994 + 1 \times 0.1998 + 1 \times 0.1998 + 3 \times 0.1045 + 4 \times 0.0604 + 5 \times 0.0361)/0.1998 = 6.2040$$

$$\frac{(AW)_3}{W_3} = (1/3 \times 0.3994 + 1 \times 0.1998 + 1 \times 0.1998 + 3 \times 0.1045 + 4 \times 0.0604 + 5 \times 0.0361)/0.1998 = 6.2040$$

$$\frac{(AW)_4}{W_4} = (1/4 \times 0.3994 + 1/3 \times 0.1998 + 1/3 \times 0.1998 + 1 \times 0.1045 + 3 \times 0.0604 + 4 \times 0.0361)/0.1045 = 6.3937$$

$$\frac{(AW)_5}{W_5} = (1/5 \times 0.3994 + 1/4 \times 0.1998 + 1/4 \times 0.1998 + 1/3 \times 0.1045 + 1 \times 0.0604 + 3 \times 0.0361)/0.0604 = 6.4014$$

$$\frac{(AW)_6}{W_6} = (1/6 \times 0.3994 + 1/5 \times 0.1998 + 1/5 \times 0.1998 + 1/4 \times 0.1045 + 1/3 \times 0.0604 + 1 \times 0.0361)/0.0361 = 6.4467$$

$$\lambda_{max} = \sum_{i=1}^{n}\frac{(AW)_i}{nW_i} = \frac{(6.4151 + 6.2040 + 6.2040 + 6.3937 + 6.4014 + 6.4467)}{6} = 6.0719$$

Thus,

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{6.0719 - 6}{6-1} = 0.0144$$

Table 4.4 A-Bi Compare judgment matrix and its eigenvalue

A-Bi	B1	B2	B3	B4	B5	B6	W	
B1	1	3	3	4	5	6	0.3994	λ=6.0719 CI=0.0144 RI=1.24 CR=0.0116
B2	1/3	1	1	3	4	5	0.1998	
B3	1/3	1	1	3	4	5	0.1998	
B4	1/4	1/3	1/3	1	3	4	0.1045	
B5	1/5	1/4	1/4	1/3	1	3	0.0604	
B6	1/6	1/5	1/5	1/4	1/3	1	0.0361	

$CR=CI/RI=0.0116<0.1$

It indicates that the judgment matrix has a more satisfactory consistency and the weight distribution is reasonable. Therefore, the weight of the first level of evaluation indexes (economic development, resource utilization, environmental protection, ecological civilization, park management, social progress) is *W*=（0.3994，0.1998，0.1998，0.1045，0.0604，0.0361）.

Using the same method to judge the importance of the evaluation index of state C and variable M respectively, the weights of state C and variable M can be obtained respectively.

Table 4.5 B1-C compares judgment matrix and its eigenvalue

B1	C1	C2	W	
C1	1	1/5	0.1667	λ=2 CI=0 RI=0 CR=0
C2	5	1	0.8333	

$CR=CI/RI=0<0.1$

Table 4.6 B2-C comparison judgment matrix and its eigenvalue

B2	C3	C4	W	
C3	1	3	0.75	λ=2 CI=0 RI=0 CR=0
C4	1/3	1	0.25	

$CR=CI/RI=0<0.1$

Table 4.7 B3-C comparison judgment matrix and its eigenvalue

B3	C5	C6	W	λ=2 CI=0 RI=0 CR=0
C5	1	4	0.8	
C6	1/4	1	0.2	

CR=*CI*/*RI*=0＜0.1

Table 4.8 B4-C comparison judgment matrix and its eigenvalue

B4	C7	C8	W	λ=2 CI=0 RI=0 CR=0
C7	1	1/3	0.25	
C8	3	1	0.75	

CR=*CI*/*RI*=0＜0.1

Table 4.9 B5-C comparison judgment matrix and its eigenvalue

B5	C9	C10	W	λ=2 CI=0 RI=0 CR=0
C9	1	1/4	0.2	
C10	4	1	0.8	

CR=*CI*/*RI*=0.0116＜0.1

Table 4.10 B6-C comparison judgment matrix and its eigenvalue

B6	C11	C12	W	λ=2 CI=0 RI=0 CR=0
C11	1	4	0.8	
C12	1/4	1	0.2	

CR=*CI*/*RI*=0＜0.1

Table 4.11 C1-M comparison judgment matrix and its eigenvalue

C1	M1	M2	M3	M4	M5	M6	W	
M1	1	1/2	1/3	1/4	1/5	2	0.0641	λ=6.1225 CI=0.0245 RI=1.24 CR=0.0198
M2	2	1	1/2	1/3	1/4	3	0.1006	
M3	3	2	1	1/2	1/3	4	0.1596	
M4	4	3	2	1	1/2	5	0.2504	
M5	5	4	3	2	1	6	0.3825	
M6	1/2	1/3	1/4	1/5	1/6	1	0.0428	

CR=*CI*/*RI*=0.0198＜0.1

Table 4.12 C2-M comparison judgment matrix and its eigenvalue

C2	M7	M8	M9	M10	M11	W	
M7	1	1	3	4	6	0.3571	λ=5.0586 CI=0.0147 RI=1.12 CR=0.0131
M8	1	1	3	4	6	0.3571	
M9	1/3	1/3	1	2	4	0.1499	
M10	1/4	1/4	1/2	1	2	0.0867	
M11	1/6	1/6	1/4	1/2	1	0.0492	

CR=CI/RI=0.0131＜0.1

Table 4.13 C3-M comparison judgment matrix and its eigenvalue

C3	M12	M13	M14	M15	W	
M12	1	4	3	7	0.5505	λ=4.1199 CI=0.04 RI=0.9 CR=0.0444
M13	1/4	1	1/3	3	0.1295	
M14	1/3	3	1	4	0.2601	
M15	1/7	1/3	1/4	1	0.0599	

CR=*CI*/*RI*=0.0444＜0.1

Table 4.14 C4-M comparison judgment matrix and its eigenvalue

C4	M16	M17	W	
M16	1	1/5	0.1667	λ=2 CI=0 RI=0 CR=0
M17	5	1	0.8333	

CR=*CI*/*RI*=0＜0.1

Table 4.15 C5-M comparison judgment matrix and its eigenvalue

C5	M18	M19	M20	M21	M22	M23	W	
M18	1	3	2	4	5	6	0.3813	λ=6.1327 CI=0.0265 RI=1.24 CR=0.0214
M19	1/3	1	1/2	2	3	5	0.1651	
M20	1/2	2	1	3	4	5	0.2493	
M21	1/4	1/2	1/3	1	2	3	0.0996	
M22	1/5	1/3	1/4	1/2	1	2	0.0635	
M23	1/6	1/5	1/5	1/3	1/2	1	0.0412	

CR=*CI*/*RI*=0.0214＜0.1

Table 4.16 C6-M comparison judgment matrix and its eigenvalue

C6	M24	M25	M26	M27	M28	M29	M30	M31	M32	W	
M24	1	5	1	6	1	1	1	2	3	0.1593	λ=9.1203 CI=0.015 RI=1.45 CR=0.0104
M25	1/5	1	1/5	3	1/5	1/5	1/5	1/3	1/2	0.0348	
M26	1	5	1	6	1	1	1	2	3	0.1593	
M27	1/6	1/3	1/6	1	1/6	1/6	1/6	1/5	1/4	0.0218	
M28	1	5	1	6	1	1	1	2	3	0.1593	
M29	1	5	1	6	1	1	1	2	3	0.1593	
M30	1	5	1	6	1	1	1	2	3	0.1593	
M31	1/2	3	1/2	5	1/2	1/2	1/2	1	2	0.0894	
M32	1/3	2	1/3	4	1/3	1/3	1/3	1/2	1	0.0575	

$CR=CI/RI=0.0104<0.1$

Table 4.17 C7-M comparison judgment matrix and its eigenvalue

C7	M33	M34	M35	M36	W	
M33	1	1/2	3	4	0.3031	λ=4.1145 CI=0.0382 RI=0.9 CR=0.0424
M34	2	1	4	5	0.4869	
M35	1/3	1/4	1	3	0.1395	
M36	1/4	1/5	1/3	1	0.0705	

$CR=CI/RI=0.0424<0.1$

Table 4.18 C8-M comparison judgment matrix and its eigenvalue

C8	M37	M38	M39	W	
M37	1	2	4	0.5584	λ=3.0183 CI=0.0091 RI=0.58 CR=0.0158
M38	1/2	1	3	0.3196	
M39	1/4	1/3	1	0.1220	

$CR=CI/RI=0.0158<0.1$

Table 4.19 C9-M comparison judgment matrix and its eigenvalue

C9	M40	M41	M42	M43	W	
M40	1	1/6	1/5	1/2	0.0648	λ=4.0936 CI=0.0312 RI=0.9 CR=0.0347
M41	6	1	3	5	0.5594	
M42	5	1/3	1	3	0.2688	
M43	2	1/5	1/3	1	0.1070	

$CR=CI/RI=0.0347<0.1$

Table 4.20 C10-M comparison judgment matrix and its eigenvalue

C10	M44	M45	M46	W	λ=3.0858 CI=0.0429 RI=0.58 CR=0.0739
M44	1	5	4	0.6738	
M45	1/5	1	1/3	0.1007	
M46	1/4	3	1	0.2255	

CR=*CI*/*RI*=0.0739＜0.1

Table 4.21 C11-M comparison judgment matrix and its eigenvalue

C11	M47	M48	W	λ=2 CI=0 RI=0 CR=0
M47	1	1/3	0.25	
M48	3	1	0.75	

CR=*CI*/*RI*=0＜0.1

Table 4.22 C12-M comparison judgment matrix and its eigenvalue

C12	M49	M50	W	λ=2 CI=0 RI=0 CR=0
M49	1	3	0.75	
M50	1/3	1	0.25	

CR=*CI*/*RI*=0＜0.1

4.2 A Case Study of Eco-Industrial Park Circular Economy

4.2.1 Park Introduction

Tianjin Economic-Technological Development Area (hereafter referred to as the "TEDA") was established on December 6th, 1984 with the approval from the State Council. It was one of the first state-level development areas. The TEDA passed the review of relevant NDRC experts on October 29th, 2006 and became one of the first 11 national circular economic pilot park. Then on May 20th, 2008, the TEDA was formally awarded the title of National Eco-industrial Demonstration Park by the Ministry of Environmental Protection of the People's Republic of China, the Ministry of Commerce of the People's Republic of China, and the Ministry of Science and Technology of the People's Republic of China.

The TEDA has gradually transformed into a new industrial district from a single industrial area through the 30 years development. As of the end of 2010, the TEDA has 9546 domestic enterprises with the total registered capital of RMB 177.06853 billion Yuan, and more than 3300 foreign-invested enterprises with the total investment over 15 billion dollars. Presently, the TEDA has nine industrial system - eight pillar industries of electronic information, biomedicine, food & be-verages, automobiles, equipment manufacturing, petroleum & chemicals, aero-space, new energy & new materials, as well as the modern service industry. Centered on the eight pillar industries, TEDA has formed a eco-industrial prototype characterized by diversified business types, close product chain relations, closed flow of resources, and efficient utilization of resources by continuously promoting industrial structure optimization & upgrading, carrying out industrial ecology, and improving industry aggregation and correlation.

Firstly, the electronic communications industry chain. With Motorola as the core, the joint cooperation of more than 20 telecommunications companies in the surrounding area has formed the industrial chain. These electronics and microelectronics manufacturers cooperate with the companies that utilize electronic waste to form a mutually beneficial symbiotic relationship in the exchange of products and by-products among enterprises.

Secondly, machinery manufacturing industry chain. With a large number of Japanese-funded and Korean-funded automobile manufacturing industries as the mainstay, the joint recycling of related resources such as scrap, scrap aluminum and waste lead together formed the industrial chain of "resources-products-waste-renewable resources".

Thirdly, the biomedical industry chain. Through biological treatment, medical solid waste can be transformed into high-quality organic fertilizer and applied to the surrounding green space and farmland.

Fourthly, food and beverage industry chain. The formation of the instant noodles, beverages and other leading products, waste water, waste noodles and other comprehensive utilization of food waste upstream and downstream product industry chain.

Fifthly, the energy infrastructure industry chain. A symbiotic chain system including wastewater treatment, energy supply and reclaimed water utilization has been formed. Cross-industry ecologic symbiosis with horizontal coupling and vertical closure within the region has been achieved.

4.2.2 Evaluation of Coordination development and Circular Economy

4.2.2.1 Index Data Acquisition

The data of the variable layer quantitative indexes are mainly from TEDA 2010 Development Report, 2011 Tianjin Statistical Yearbook, industrial park statistical data, relevant regional environmental quality report, governmental research data, and relevant literature data and field investigation etc.

4.2.2.2 Evaluation Index Value Calculation

Please refer to Table 4.23 for TEDA 2010 Status Data & Evaluation and Calculation Results.

Firstly, Actual Value(v_i) were calculated by formulas shown in Chapter4.1.5, like as Per-capital Industrial Added Value (v_1):

$$\text{Per-capital Industrial Added Value} = \frac{\text{Industrial Added Value (ten thousand yuan)}}{\text{employment (capital)}}$$

Secondarily, Classical Field (ai, bi) was determined:

According to the calculation method described in chapter 2.2.2.4:

Due to the variety of index types, different methods should be used to determine the classical domain(Zhu Li,2011). The methods adopted in this paper are:

① Refer to the national standard documents issued by the Ministry of Environmental Protection, such as “Comprehensive Eco-Industrial Park Standards” (HJ274-2009), “Environmental Air Quality Standards” (GB3095-1996) and “Acoustic Environmental Quality Standards” (GB3096-2008). The upper or lower limit specified in the national standard is a limit of the classic domain, and the other limit of the classic domain refers to the medium- and long-term planning value of the park or the advanced level of the domestic and foreign parks. When some indexes whose classical domain values are very difficult to determine, the upper limit of the positive index is ten times of the lower limit, and the lower limit of the negative index is one tenth of the upper limit(Zhu Li,2011).

② Take a combination method of research and expert consultation. According investigating the published data of the typical eco-industrial park and their statistics data of its internal statistical departments. And the classical domain of the indexes is determined by consulting industry experts basing on the obtained data.(Zhu Li,2011).

Thirdly, $k(v_1)$ ware calculated by:

According to the calculation formula described in chapter 3.7.2.2, to check the type (positive or inverse) of each index in Table 4.26, and select the corresponding formula to calculate. The calculation process is as follows:

①Positive index(M1 as an example):

$$k(v_i)=\begin{cases}1 & v_i>b_i\\ \dfrac{v_i-a_i}{b_i-a_i} & v_i\in(a_i,b_i)\\ 0 & v_i<a_i\end{cases}$$

There v_1=38.41, (a_1, b_1)=(15,100),

Thus,

$$k(v_1)=\frac{38.41-15}{100-15}=0.275$$

②Inverse index(M12 as an example):

$$k(v_i)=\begin{cases}0 & v_i>b_i\\ \dfrac{a_i-v_i}{a_i-b_i} & v_i\in(a_i,b_i)\\ 1 & v_i<a_i\end{cases}$$

There v_{12}=0.142, (a_{12}, b_{12})=(0.05,0.5),

Thus,

$$k(v_{12})=\frac{0.05-0.142}{0.05-0.5}=0.204$$

Table 4.23 Status data & evaluation and calculation results of evaluation indexes

Criterion Layer Weight	Status Layer Weight	Index Layer	Variable Layer Weight	Actual Value(v_i)	Classical Field (ai, bi)	Correlation k(vi)
0.3994 B1	0.1667 C1	M1	0.0641	38.41[1]	(15,100)[6]	0.275
		M2	0.1006	25.1[1]	（20.8,30）[4,5]	0.467
		M3	0.1596	23.1[1]	（43,80）[5]	0
		M4	0.2504	18.36[1]	（2.5,25）[5]	0.705
		M5	0.3825	6.25[1]	（1.25,10.3）[5]	0.552
		M6	0.0428	0.2[1]	（0.034,0.34）[5]	0.542
	0.8333 C2	M7	0.3571	3.15[2]	（1.8,4.6）[5]	0.482
		M8	0.3571	45.3[2]	（20,60）[5,6]	0.6325
		M9	0.1499	60[4]	（40,90）[4]	0.4
		M10	0.0867	100[2]	(60,100)[4]	1
		M11	0.0492	80[2]	(60,100)[4]	0.5
0.1998 B2	0.75 C3	M12	0.5505	0.142[1]	（0.05,0.5）[6]	0.204
		M13	0.1295	4.05[1]	（0.9,9）[6]	0.389
		M14	0.2601	0.778[2]	（0.06,0.6）[6]	0
		M15	0.0599	0.45[2]	（0.06,0.55）[6]	0.796
	0.25 C4	M16	0.1667	87.5[1]	(75,100)[6]	0.5
		M17	0.8333	90.86[1]	(85,100)[6]	0.391
0.1998 B3	0.8 C5	M18	0.3813	2.27[1]	（0.8,8）[6]	0.204
		M19	0.1651	25.55[1]	(10,100)[6]	0.173
		M20	0.2493	0.24[2]	（0.1,1）[6]	0.156
		M21	0.0996	0.227[2]	（0.1,1）[6]	0.141
		M22	0.0635	0.573[2]	（0.03,0.3）[6]	0
		M23	0.0412	-0.418[2]	（0.02,0.2）[6]	1
	0.2 C6	M24	0.1593	100[1]	(95,100）[6]	1
		M25	0.0348	5.96[2]	（5,20）[4,6]	0.064
		M26	0.1593	100[2]	（90, 100）[6]	1
		M27	0.0218	9.26[2]	（5,20）[4,6]	0.284
		M28	0.1593	100[1]	(95,100）[6]	1
		M29	0.1593	100[1]	（100, 100[6]）	1
		M30	0.1593	100[1]	(95,100）[6]	1
		M31	0.0894	52.9[1]	（50,60）[6]	0.29
		M32	0.0575	67[1]	（55,70）[6]	0.8
0.1045 B4	0.25 C7	M33	0.3031	100[1]	(95,100）[3,4]	1
		M34	0.4869	81.37[1]	（75, 100）[6]	0.2548
		M35	0.1395	24.7[1]	（30,60）[3,4]	0
		M36	0.0705	93.3[4]	（90, 100）[6]	0.33
	0.75 C8	M37	0.5584	2[2,3]	（1.6,3）[5]	0.286
		M38	0.3196	48.4[2]	（15,60）[6]	0.742
		M39	0.122	25.7[3]	（20,40）[4,5]	0.285
0.0604 B5	0.2 C9	M40	0.0648	100[2]	（80, 100）[6]	1
		M41	0.5594	90[2,4]	（60, 100）[6]	0.75
		M42	0.2688	100[2,4]	（60, 100）[5]	1
		M43	0.107	90[2]	（80, 100）[6]	0.5
	0.8 C10	M44	0.6738	95[3]	（60, 100）[5]	0.875
		M45	0.1007	90[2,4]	（40, 100）[6]	0.83
		M46	0.2255	43[2]	（75, 100）[5]	0
0.0361 B6	0.8 C11	M47	0.2	48.4[1]	（40,80）[4]	0.21
		M48	0.8	4.79[2,3]	（3,10）[5]	0.257
	0.2 C12	M49	0.75	35.9[3]	（20,40）[5]	0.795
		M50	0.25	46.9[3]	（30,80）[4]	0.338

Source: 1) TEDA 2010 Development Report; 2) Industrial Park Statistical Data Report; 3) 2010 Tianjin Statistical Yearbook; 4) Governmental Research Data; 5) Relevant Literature data; 6) National and industry standards

Calculated weighted comprehensive evaluation index:

① Comprehensive efficiency index. It include eco-industrial park economic development, resource utilization, environmental protection, ecological civilization, park management and social progress index φ_1, φ_2, φ_3, φ_4, φ_5, φ_6. For the i[th] evaluation object (sample).

$$\varphi_{ti} = \sum_{j=1}^{n} W_{ij} k(v)_{ij}$$

Where φ_{ti} represents the corresponding indicator of the i[th] evaluation object (sample); t=1,2,3,4,5,6 respectively represent the economic development, resource utilization, environmental protection, ecological civilization, park management, social progress index of the i[th] evaluation object (sample); $k(v)_{ij}$ represents the membership function value of the j[th] index current status data of the i[th] evaluation object (sample); W_{ij} represents the j[th] index weight coefficient of the i[th] evaluation object (sample); n represents the indexes number of each criterion layer index.

②Comprehensive development coefficient. It reflects the overall level and the development level of various subsystems in the eco-industrial park during the evaluation period.

$$U = \sum_{t=1}^{6} W_t \varphi_{ti}$$

③ Development coordination coefficient. It is a measure of the subsystems' coordination relationship of the eco-industrial park, calculated by the following formula:

$$H_i = 1 - S_i / \overline{F_i}$$

Where, S_i represents the efficiency index standard deviation of i[th] evaluation object's each subsystem; $\overline{F_i}$ represents the average of the economic development, resource utilization, environmental protection, ecological civilization, and park management index of the i[th] sample. When the values of φ_1, φ_2, φ_3, φ_4, φ_5, φ_6 are closer, it indexes (economic development, resource utilization, environmental protection, ecological civilization, park management, and social progress) of the subsystems in the eco-industrial park are more coordinated, and the value is closer to 1, otherwise the more uncoordinated, and its value is closer to 0.

Please refer to Table 4.24 for the coordination coefficient and comprehensive cyclic indexes of each subsystem of the eco-industrial park.

Table 4.24 Calculation results of the coordination coefficient of TEDA subsystems in 2010

φ_1	φ_2	φ_3	φ_4	φ_5	φ_6
0.5536	0.2601	0.3358	0.4363	0.6999	0.3342

Standard Derivation S_i	Development Coordination Coefficient H_i	Average Value $\overline{F_i}$	Comprehensive Development Coefficient U
0.1499	0.6567	0.4366	0.4401

4.2.2.3 Evaluation Results Analysis

(1) Analysis of characterization factor

Seen from the efficiency indexes of the six subsystems of the general eco-industrial park evaluation indexes system, the economic development efficiency index is 0.5536, the resource utilization efficiency index is 0.2601, the environmental protection efficiency index is 0.3358, the ecological civilization efficiency index is 0.4363, the park administration efficiency index is 0.6999, and the social progress efficiency index is 0.3342. While, the park administration efficiency index is the highest, and the resource utilization efficiency index is the lowest. The former is 2.7 times of the latter. It’s found from Table 5.23 that the comprehensive development coefficient of the TEDA eco-industrial park is 0.4401, which indexes that the comprehensive development level is not high. It’s known from Table 5.24 that the development of the TEDA eco-industrial park falls into a weak loop, as the upper limit value (positive index) or the lower limit value (negative index) of the classical field in the index system are taken from the advanced level of developed countries or the optimal level of domestic parks of the same kind during the same period. Therefore, the evaluation results conform to the objective facts. It follows that TEDA needs to make efforts to achieve the stable and sustainable circular economic development status and rank among advanced domestic parks or reach world first-class development level.

(2) Analysis of impact factors

It's found from formula that the factors impacting the general eco-industrial park coordinated development degree are the subsystem efficiency indexes. When the subsystem efficiency indexes are much closer, the park coordinated development degree is much higher. Then, it's concluded from the above analysis that the resource utilization efficiency index, the environmental protection efficiency index, the ecological civilization efficiency index, and the social progress efficiency index of the TEDA eco-industrial park are relatively low and below 0.5, which is the major factor to lead the weak coordination of the TEDA eco-industrial park system development. It's found from formula that the factors impacting the general eco-industrial park Comprehensive Development Level are the weight of each subsystem and their efficiency indexes.

Seen from the weight of each index system layer, the weight of economic development is 0.3994, the weight of resource utilization is 0.1998, the weight of environmental protection is 0.1998, the weight of ecological civilization is 0.1045, the weight of park administration is 0.0604, and the weight of social progress is 0.0361. Economic development has the greatest impact on the eco-industrial park coordinated development degree & comprehensive development level, followed by resource utilization and environmental protection, and then ecological civilization, park administration, and social progress in turn.

(3) Analysis of improvement strategies

It's concluded from the above analysis that the TEDA eco-industrial park should take the following measures to realize coordinated park system development and improve comprehensive development level: increase scientific research input funds, reinforce scientific innovation and technical R&D; reduce comprehensive energy consumption per unit of industrial added value, improve comprehensive utilization ratio of industrial solid wastes; decrease wastewater production every 10 thousand yuan industrial added value and COD production every 10 thousand yuan industrial added value; better air quality and increase the ratio of environ-mental protection in GDP; improve the ratio of professionals in environmental administration organizations; improve the ratio of employment added by circular economy.

4.2.3 Time Series Evaluation of Enterprise Information Portal

Based on the data obtained by TEDA's enterprise information portal, a part of the evaluation indexes were calculated from 2010 to 2013, the result was shown in Table 4.25.

Table 4.25 The time series result of evaluation indexes (2010-2013)

Index Layer	Actual Value (v_i)				Correlation k(vi)			
	2010	2011	2012	2013	2010	2011	2012	2013
M1	38.41	43.44	48.52	49.56	0.28	0.33	0.39	0.41
M2	25.10	*	20.40	17.50	0.47	**	0.00	0.00
M3	23.10	*	17.66	9.05	0.00	**	0.00	0.00
M4	18.36	*	22.24	24.87	0.70	**	0.88	0.99
M5	6.25	6.48	6.75	7.04	0.55	0.58	0.61	0.64
M6	0.20	0.21	0.23	0.25	0.54	0.58	0.64	0.71
M8	45.30	34.32	31.32	20.45	0.63	0.36	0.28	0.01
M12	0.14	0.14	0.14	0.14	0.20	0.19	0.19	0.19
M13	4.05	3.78	3.54	3.32	0.39	0.36	0.33	0.30
M14	0.78	*	12.05	8.80	0.00	**	0.00	0.00
M15	0.45	*	0.44	0.33	0.80	**	0.78	0.55
M16	87.50	87.50	87.75	87.80	0.50	0.50	0.51	0.51
M17	90.86	90.86	95.26	96.00	0.39	0.39	0.68	0.73
M18	2.27	1.38	1.08	1.02	0.20	0.08	0.04	0.03
M19	25.55	21.33	21.20	19.15	0.17	0.13	0.12	0.10
M24	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M25	5.96	8.09	-6.93	*	0.06	0.21	0.00	**
M26	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M28	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M29	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M30	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M31	52.90	52.90	53.60	51.60	0.29	0.29	0.36	0.16
M32	67.00	67.00	63.50	61.90	0.80	0.80	0.57	0.46
M33	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M34	81.37	81.36	76.44	*	0.25	0.25	0.06	**
M35	24.70	*	24.61	27.05	0.00	**	0.00	0.00
M42	100.00	100.00	100.00	100.00	1.00	1.00	1.00	1.00
M47	48.40	25.00	27.20	26.27	0.21	0.00	0.00	0.00

Source: TEDA's enterprise information portal;

*: Missing data in TEDA's enterprise information portal;

**: Unable to calculate data due to missing of TEDA's enterprise information portal.

(1) B1 Economic Development Layer

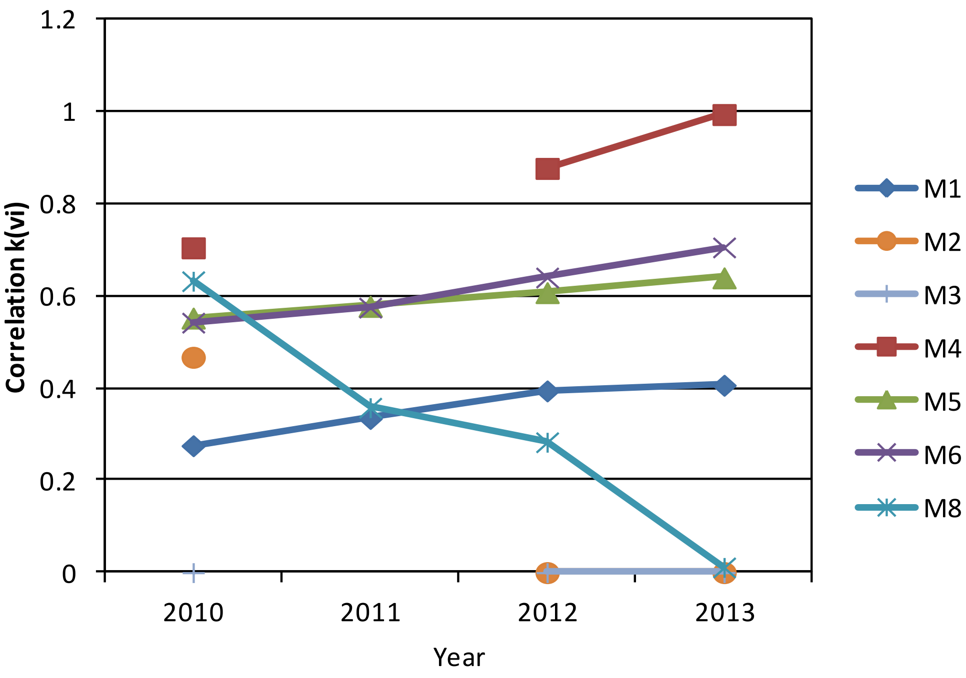

Figure 4.1 The time series trend of the B1-layer's evaluation indexes

The indexes of M1, M2, M3, M4, M5, M6, and M8 are positive indexes from Table 3.26, this means that k(vi) is in the (0,1) interval, closer 1 better result.

The Figure 4.1 shown: M1, M2, M3, M4, M5, and M6 are closer to 1 with year; and M8 is farther to 1 with year. M1, M2, M3, M4, M5, and M6 presented a better trend from 2010 to 2013; but M8 presented a worse trend from 2010 to 2013.

(2) B2 Resource Utilization Layer

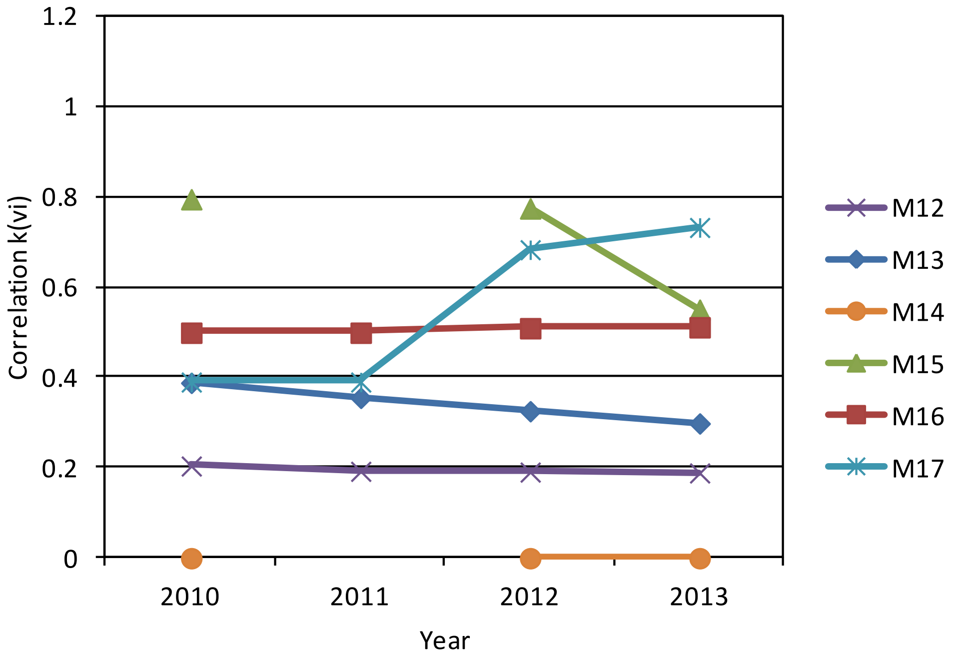

Figure 4.2 The time series trend of the B2-layer's evaluation indexes

The indexes of M12, M13, M14, and M15 are inverse indexes; the indexes of M16 and M17 are positive indexes.(shown in Table 3.26) This means that k(vi) of M12, M13, M14, and M15 are closer 0 better result; k(vi) of M16 and M17 are closer 1 better result.

The Figure 4.2 shown: M12, M13, M14, and M15 are closer to 0 with year; M16 and M17 are closer to 0 with year. M12, M13, M14, M15, M16, and M17 presented a better trend from 2010 to 2013.

(3) B3 Environmental Protection

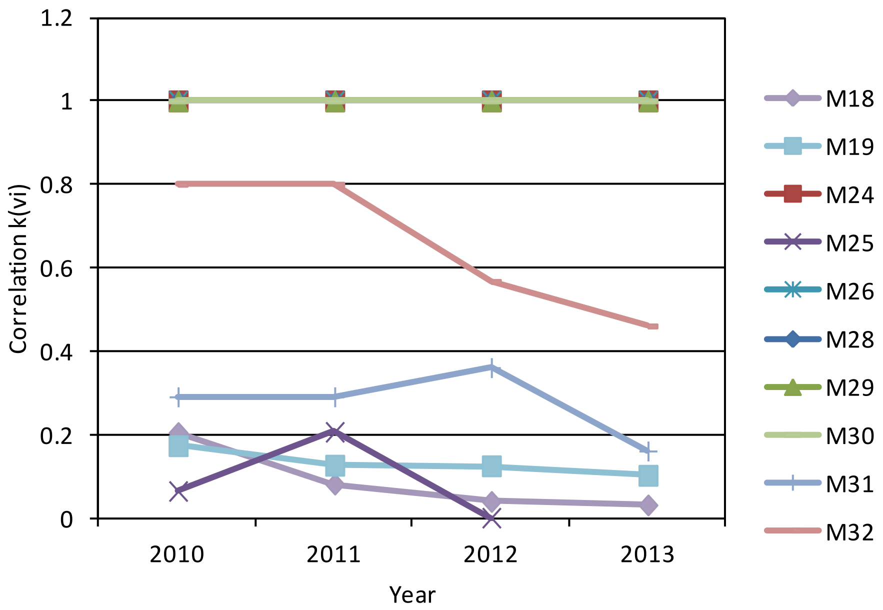

Figure 4.3 The time series trend of the B3-layer's evaluation indexes

The indexes of M18, M19, M31 and M32 are inverse indexes; the indexes of M24, M25, M26, M28, M29 and M30 are positive indexes.(shown in Table 3.26) This means that k(vi) of M18, M19, M31 and M32 are closer 0 better result; k(vi) of M24, M25, M26, M28, M29 and M30 are closer 1 better result.

The Figure 4.3 shown: M24, M26, M28, M29 and M30 keep 1; M18, M19, M31 and M32 are closer to 0 with year; but M25 became trend closed to 1. M24, M26, M28, M29 and M30 keep a better trend; M18, M19, M31 and M32 presented a better trend from 2010 to 2013; but M25 became a worse trend in 2012.

(4) B4 Eco-friendly Layer, B5 park administration, and B6 social progress

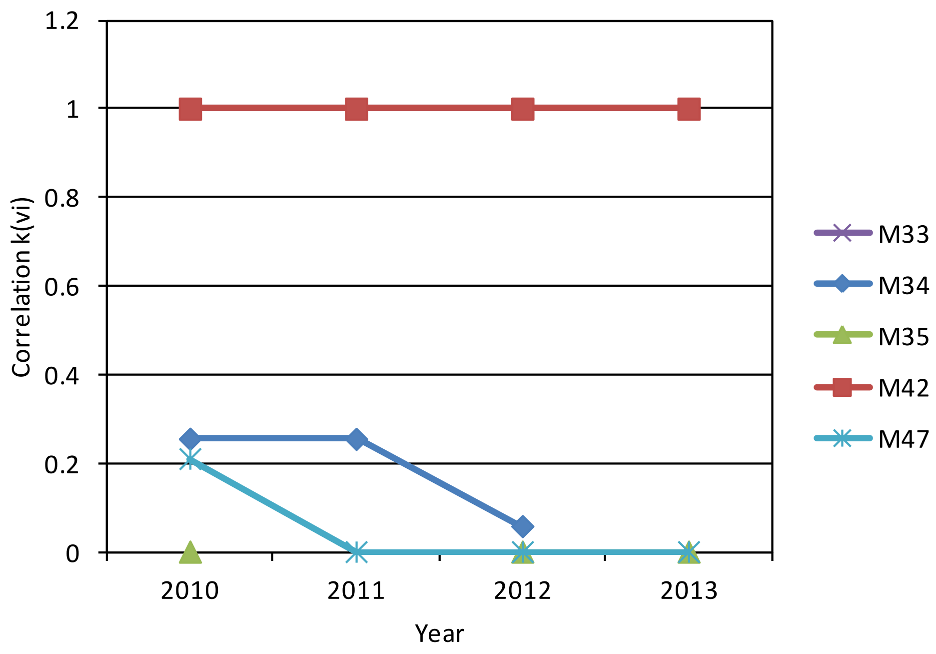

Figure 4.4 The time series trend of the B4, B5 and B6 layer's evaluation indexes

The indexes of M33, M34, M35, M42, and M47 are positive indexes.(shown in Table 3.26) This means that k(vi) of M33, M34, M35, M42, and M47 are closer 1 better result.

The Figure 4.4 shown: M33 and M42 keep 1; M35 keep 0; and M34 and M47 are closer to 0 with year. M33 and M42 keep a better trend; M35 keep a worse trend; and M34 and M47 presented a worse trend from 2010 to 2013.

(5) Analysis summary

Based on the trend analysis of 28 indexes from 2010 to 2013, the indexes presented a better trend except of M8, M25, M34, M35 and M47. The slowdown of Rate of Industrial Wastewater Discharge Reduction M25 in 2013 is due to the slow development of high-tech enterprises. The park should focus on developing high-tech industries and add new impetus to energy conservation and emission reduction. The development of high-tech enterprises will reduce the emission of polluting waste (waste water and waste gas). The park should change the current situation of low green coverage rate, and the low green coverage rate will affect the development of circular economy in the park.

M8- Percentage of High-tech Industry Output in Total Industrial Output Value

M25- Rate of Industrial Wastewater Discharge Reduction

M34- Rate of Secondary Air Quality Standard Compliance

M35- Rate of Park Greenery Coverage

M47- Ratio of the Number of Tertiary Industry Employees

4.3 Summary

On the basis of a comprehensive analysis of the current situation of eco-industrial park development in the world and the construction of eco-industrial park evaluation index system, this chapter aims at the economic development, resource utilization, environmental protection, ecological civilization, park management and social progress of eco-industrial park Based on the theory of extenics theory, flow analysis theory, qualitative and quantitative analysis, and analytic hierarchy process, the index system and evaluation model of the coordinated development of the integrated eco-industrial parks are established. The main achievements are obtained the following results:

(1) The main theories and methods of building eco-industrial park evaluation index system at home and abroad are summarized, including: eco-efficiency method, flow analysis method and index system method.

(2) Based on the idea of AHP, the index system of eco-industrial park comprehensive evaluation is divided into four levels: taking the coordinated development of the park system and the comprehensive development level as the general objective of the eco-industrial park evaluation; according to the type characteristics of the eco-industrial park, The index system is divided into six first-level indexes of economic development, resource utilization, environmental protection, ecological civilization, park management and social progress. Each of the first-level indexes is divided into two second-level indexes of rigid index and flexible index. The rigid index Including economic strength, resource consumption, sewage intensity, ecological construction, management level, employment status and happiness index 7, reflecting the development status and construction effect of eco-industrial park; flexible indexes include economic development potential, recycling, pollution control , Ecological improvement potentiality and infrastructure support capacity, reflecting the stability, sustainability and coordination of the

eco-industrial park development. At last, we use frequency statistics and expert consultation methods to select and determine a number of evaluation indexes.

(3) The overlapping analysis of the primary indexes, indexes of the same state level under a number of indexes between the assignment, independent relationship assignment is 0, equal relationship assignment is 1, connotation or information part of the overlap assignment. Lists the matrix of relations between indexes, summarizes the columns by columns, removes columns and larger indexes (indicating that the indexes have partially overlapped with each other), retains columns, and smaller indexes, selects and finalizes Eco-industrial park comprehensive evaluation of the specific indexes.

(4) The multi-level extension comprehensive evaluation method is adopted to build a system of coordinated development degree and comprehensive development level of integrated eco-industrial park. The model is used to evaluate and analyze TEDA eco-industrial park. The evaluation results show that economic development, resource utilization, environment The coordinated development of protection, ecological civilization, park management and social progress is weak and belongs to the weak coordination. Its development level is relatively low compared with the advanced parks in the same type and developed countries in the country and belongs to the weak cycle. TEDA into the stable and sustainable development of circular economy still need hard work, and the impact of the evaluation results were analyzed and put forward improved strategies and measures.

5. Comprehensive Evaluation Model of Enterprise Circular Economy

5.1 Determination of Evaluation Criteria and Index Weight

5.1.1 Evaluation Criteria Determination

After the index screening is completed, the evaluation standard (ideal value) of the circular economy development level of the enterprise shall be determined, that is to say, the maximum value (positive direction, benefit, extremely large index) and the minimum value (negative direction, cost / loss, Very small index).

For enterprises, the comprehensive evaluation of the ideal value should be combined with the type of business and recycling economy "3R" principle, proceed from reality, follow the " General guideline of standard system for circular economy of industrial enterprises and parks" (GB/T 33751-2017) and “Technical guidelines of circular economy performance evaluating”(GB/T34345-017); as well as the industry technical standards formulated by the relevant industries; and the research results of the State Environmental Protection Academy, the Circular Economy Statistical Yearbook and the government departments show the optimal value of the industry both at home and abroad and rationally design and evaluate the ideal values.

5.1.2 Index Weight Determination

Analytic Hierarchy Process (AHP) is used to carry out weight analysis on the indexes of the enterprise circular economy evaluation index system. First of all, the analysis of the criteria layer, for ease of representation, with C1 on behalf of economic benefits, C2 on behalf of resource and energy consumption, C3 on behalf of waste emissions, C4 on behalf of recycling, C5 on behalf of environmental protection and technological innovation, C6 on behalf of business management and social benefit.

In this paper, questionnaire method and expert consultation method are used to determine the index weights, the questionnaires shown in Appendix 4, experts’ score results are summarized in Table 5.1.

Table 5.1 Experts' score results of enterprise index weight determination

Criterion Layer	Average Score	Indexes	Average Score
Economic Benefits	6.0	Growth Rate of Sales Revenue	5.1
		Net Return on Assets	5.3
		Economic Output Density	8.3
		Economic Benefits from the Implementation of Circular Economy	8.5
Resource & Energy Consumption	8.2	Raw Material Consumption Per Ten Thousand Yuan Output Value	7.3
		Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value	7.0
		Fresh Water Consumption Per Ten Thousand Yuan Output Value	7.1
		Enterprise Clean Energy Utilization Rate	4.0
		Renewable Material Utilization Rate	4.1
		Energy Utilization Efficiency	8.4
		Raw Material Utilization Rate	8.7
Waste Discharge	7.8	Standard Discharge Rate of Wastewater	4.0
		Standard Discharge Rate of Exhaust Gas	4.3
		Safe Disposal Rate of Hazardous Wastes	4.5
		Wastewater Discharge Per Ten Thousand Yuan Output Value	8.3
		COD Emission Per Ten Thousand Yuan Output Value	7.3
		Exhaust Emissions Per Ten Thousand Yuan Output Value	7.0
		Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	7.1
		Solid Waste Emission Per Ten Thousand Yuan Output Value	8.3
Recycle & Reuse	8.8	Intermediate By-products Utilization Rate	8.8
		Wastewater Comprehensive Utilization Rate	8.6
		Solid Waste Comprehensive Utilization Rate	8.4
		Waste Heat Utilization Rate	6.7
		Packaging Material Recycling Rate	5.0
Environmental Protection Construction & Technological Innovation Capabilities	5	Rate of Enterprise Environmental Protection Investment	8.3
		Environmental Protection Equipment Proportion	6.0
		Innovation Input Capability	5.8
		Technological R&D Capability	8.2
		Ratio of Scientific and Technical Personnel	5.5
Enterprise Management & Social Benefits	5	Enterprise Circular Economy Knowledge Training	5.1
		Enterprise Circular Economy Norms Construction	5.0
		Enterprise Information System Construction	8.3
		Employee Awareness about Environmental Protection	8.2
		Enterprise Brand Value and Social Image	5.5

Table 5.2 Index Weights Analysis of Criterion Layer

	C1	C2	C3	C4	C5	C6	Weights
C1	1	1/2	1/2	1/3	2	2	0.1173
C2	2	1	1	1/2	3	3	0.2031
C3	2	1	1	1/2	3	3	0.2031
C4	3	2	2	1	4	4	0.3383
C5	1/2	1/3	1/3	1/4	1	1	0.0690
C6	1/2	1/3	1/3	1/4	1	1	0.0690

$\lambda max=6.0412$ CI=0.0082   CR=0.0066<0.10

Table 5.3 Index Weights Analysis of Economic Benefit

C1	M1	M2	M3	M4	Weights
M1	1	1	1/2	1/2	0.1667
M2	1	1	1/2	1/2	0.1667
M3	2	2	1	1	0.3333
M4	2	2	1	1	0.3333

$\lambda max=4.00$ CI=0   CR=0<0.10

Table 5.4 Index Weights Analysis of Resource & Energy Consumption

C2	M5	M6	M7	M8	M9	M10	M11	Weights
M5	1	1	1	2	2	1/2	1/2	0.1287
M6	1	1	1	2	2	1/2	1/2	0.1287
M7	1	1	1	2	2	1/2	1/2	0.1287
M8	1/2	1/2	1/2	1	1	1/3	1/3	0.0698
M9	1/2	1/2	1/2	1	1	1/3	1/3	0.0698
M10	2	2	2	3	3	1	1	0.2371
M11	2	2	2	3	3	1	1	0.2371

$\lambda max=7.0202$ CI=0.0034   CR=0.0026<0.10

Table 5.5 Index Weights Analysis of Waste Discharge

C3	M12	M13	M14	M15	M16	M17	M18	M19	Weights
M12	1	1	1	1/3	1/2	1/2	1/2	1/3	0.0655
M13	1	1	1	1/3	1/2	1/2	1/2	1/3	0.0655
M14	1	1	1	1/3	1/2	1/2	1/2	1/3	0.0655
M15	3	3	3	1	2	2	2	1	0.2189
M16	2	2	2	1/2	1	1	1	1/2	0.1219
M17	2	2	2	1/2	1	1	1	1/2	0.1219
M18	2	2	2	1/2	1	1	1	1/2	0.1219
M19	3	3	3	1	2	2	2	1	0.2189

λmax=8.0232 CI=0.0033 CR=0.0023<0.10

Table 5.6 Index Weights Analysis of Recycle & Reuse

C4	M20	M21	M22	M23	M24	Weights
M20	1	1	1	2	3	0.2601
M21	1	1	1	2	3	0.2601
M22	1	1	1	2	3	0.2601
M23	1/2	1/2	1/2	1	2	0.1378
M24	1/3	1/3	1/3	1/2	1	0.0819

λmax=5.0099 CI=0.0025 CR=0.0022<.010

Table 5.7 Index Weights Analysis of Environmental Protection Construction & Technological Innovation Capabilities

C5	M25	M26	M27	M28	M29	Weights
M25	1	2	2	1	2	0.2857
M26	1/2	1	1	1/2	1	0.1429
M27	1/2	1	1	1/2	1	0.1429
M28	1	2	2	1	2	0.2857
M29	1/2	1	1	1/2	1	0.1429

λmax=5.00 CI=0 CR=0<0.10

Table 5.8 Index Weights Analysis of Enterprise Management & Social Benefits

C6	M30	M31	M32	M33	M34	Weights
M30	1	1	1/2	1/2	1	0.1429
M31	1	1	1/2	1/2	1	0.1429
M32	2	2	1	1	2	0.2857
M33	2	2	1	1	2	0.2857
M34	1	1	1/2	1/2	1	0.1429

$\lambda max=5.00$ CI=0 CR=0<0.10

Table 5.9 Evaluation Index System for Enterprises Circular Economy

Criterion Layer	Indexes	Weight
Economic Benefits 0.1173	Growth Rate of Sales Revenue	0.1667
	Net Return on Assets	0.1667
	Economic Output Density	0.3333
	Economic Benefits from the Implementation of Circular Economy	0.3333
Resource & Energy Consumption 0.2031	Raw Material Consumption Per Ten Thousand Yuan Output Value	0.1287
	Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value	0.1287
	Fresh Water Consumption Per Ten Thousand Yuan Output Value	0.1287
	Enterprise Clean Energy Utilization Rate	0.0698
	Renewable Material Utilization Rate	0.0698
	Energy Utilization Efficiency	0.2371
	Raw Material Utilization Rate	0.2371
Waste Discharge 0.2031	Standard Discharge Rate of Wastewater	0.0655
	Standard Discharge Rate of Exhaust Gas	0.0655
	Safe Disposal Rate of Hazardous Wastes	0.0655
	Wastewater Discharge Per Ten Thousand Yuan Output Value	0.2189
	COD Emission Per Ten Thousand Yuan Output Value	0.1219
	Exhaust Emissions Per Ten Thousand Yuan Output Value	0.1219
	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	0.1219
	Solid Waste Emission Per Ten Thousand Yuan Output Value	0.2189
Recycle & Reuse Recycle & Reuse 0.3383	Intermediate By-products Utilization Rate	0.2601
	Wastewater Comprehensive Utilization Rate	0.2601
	Solid Waste Comprehensive Utilization Rate	0.2601
	Waste Heat Utilization Rate	0.1378
	Packaging Material Recycling Rate	0.0819
Environmental Protection Construction & Technological Innovation Capabilities 0.0690	Rate of Enterprise Environmental Protection Investment	0.2857
	Environmental Protection Equipment Proportion	0.1429
	Innovation Input Capability	0.1429
	Technological R&D Capability	0.2857
	Ratio of Scientific and Technical Personnel	0.1429
Enterprise Management & Social Benefits 0.0690	Enterprise Circular Economy Knowledge Training	0.1429
	Enterprise Circular Economy Norms Construction	0.1429
	Enterprise Information System Construction	0.2857
	Employee Awareness about Environmental Protection	0.2857
	Enterprise Brand Value and Social Image	0.1429

5.2 The Application of Comprehensive Evaluation Model of Enterprise Circular Economy in Different Special Industries

5.2.1 Evaluation Index System of Power Enterprise Circular Economy

(1) The main products in the coal-fired power generation enterprises are electric energy and thermal energy. The material flow of the system originates from the input of coal resources, which consumes a large amount of fresh water during the operation of the system. Power plants produce electricity, steam and other products, there are a large number of appendages, such as waste gas, waste water, waste residue. Waste gas is generated from boiler flue gas, transportation and storage of coal dust; waste water is boiler waste water, circulating cooling waste water and domestic sewage; solid waste mainly comes from fly ash(Zhang Feng, 2012).

(2) Based on the evaluation index system of general circular economy of enterprises and combining with the severe air pollution in the power industry and the good recyclability of wastes, etc., with reference to the development model of circular economy of typical enterprises, a set of characteristic indexes Circular Economy Evaluation Index System for Power Enterprises. There are six aspects of the system, including 37 evaluation indexes at the index level, as shown in Table 6.11.

(3) Supplementary explanation of index meaning:

Non-power Output Value Proportion: Power companies in addition to power generation, the other output value accounted for the ratio of total output value. Including heat desalination, salt, ash and gypsum sales and other integrated development of the output value.

$$\text{Non-power Output Value Proportion} = \frac{\text{The Non-electricity Output Value}}{\text{The Total Output Value}} \times 100\%$$

Standard Unit Coal Consumption for Power Generation: It is a measure of the extent to which power companies use and consume coal resources, indirectly reflecting the efficiency of coal used by enterprises.

$$\text{Standard Unit Coal Consumption for Power Generation} = \frac{\text{The Standard Coal Consumption}(g)}{\text{Power generation(kWh)}}$$

Standard Unit Coal Consumption for Power Supply: It is a measure of power companies on the utilization and consumption of coal resources, indirectly reflecting the use of coal companies' efficiency.

$$\text{Standard Unit Coal Consumption for Power Supply} = \frac{\text{The Standard Coal Consumption}(g)}{\text{Power Supply(kWh)}}$$

Water Consumption for Unit Product: It reflects the degree of enterprise water use reduction indexes. Fresh water here refers to tap water that does not include reuse water and reuse water.

$$\text{Water Consumption for Unit Product} = \frac{\text{Total Fresh Water Consumption}(\text{m}^3)}{\text{Total Power Generation(ten thousand kWh)}}$$

Comprehensive Station Service Power Consumption Rate: It reflect the electricity production and living conditions of enterprises.

$$\text{Comprehensive Station Service Power Consumption Rate} = \frac{\text{Power Self - consumption}}{\text{Total Power Generation}} \times 100\%$$

Oil Consumption for Unit Product: It is an index that reflects the amount of diesel used by an organization to help generate electricity from combustion.

$$\text{Oil Consumption for Unit Product} = \frac{\text{Total Diesel Consumption(kg)}}{\text{Total Power Generation(ten thousand kWh)}}$$

Energy Utilization Efficiency: The energy efficiency of enterprises is a concentrated reflection and comprehensive index of the effective utilization of consumed energy. It is the company's total energy consumption, the percentage of energy companies' use effectively.

$$\text{Energy Utilization Efficiency} = \frac{\text{Power Generation}}{\text{Coal Consumption}} \times 100\%$$

Annual Heat-to-electric Ratio: Thermoelectric ratio is the ratio of heat and power generation (converted to heat) in a thermal power plant. Reflect the ratio of heat supply and power generation of power enterprises, indirectly reflect the use of energy by enterprises.

$$\text{Annual Heat-to-electricRatio} = \frac{\text{Heat Supply}}{\text{Power Generation}} \times 100\%$$

Rate of Environmental Noise Reaching Standards: Noise generated in the production process, after the noise, noise and other treatment, the factory environmental noise standards.

$$\text{Rate of Environmental Noise Reaching Standards} = \frac{\text{The Number of Compliance Monitoring Sites}}{\text{The Number of Monitoring Sites}} \times 100\%$$

Flue Dust Emission for Unit Product: The ratio of the total amount of soot emitted during the production of a power plant to the total power generation of the enterprise can be used to control the reduction of particulate pollutants.

$$\text{Flue Dust Emission for Unit Product} = \frac{\text{Flue Dust Emission}(t)}{\text{Power Generation(tne thousand kWh)}}$$

Sulfur Dioxide Emissions for Unit Product: Power enterprises in the production process of sulfur dioxide emissions and total electricity generation ratio can be used for atmospheric sulfur pollutant reduction control.

$$\text{Sulfur Dioxide Emissions for Unit Product} = \frac{\text{Sulfur Dioxide Emissions(t)}}{\text{Power Generation(tne thousand kWh)}}$$

Nitrogen Oxide Emissions for Unit Product: The ratio of the total amount of nitrogen oxides emitted in the production of power plants to the total power generation of the enterprise can be used to control the reduction of atmospheric nitrogen pollutants.

$$\text{Nitrogen Oxide Emissions per unit Output Value} = \frac{\text{Nitrogen Oxide Emissions(t)}}{\text{Power Generation(tne thousand kWh)}}$$

Ash Residue Production for Unit Product: the ratio of the total amount of fly ash and bottom slag generated in the power plant's production process to the total power generation of the enterprise can be used to control the reduction of solid waste pollutants.

$$\text{Ash Residue Production for Unit Product} = \frac{\text{The Amount of Ash Produced(t)}}{\text{Power Generation(tne thousand kWh)}}$$

Wastewater Production for Unit Product: The ratio of the total amount of waste water generated in the production process of an electric power plant to the total power generation of the enterprise can be used for the control of pollutant reduction.

$$\text{Wastewater Production for Unit Product} = \frac{\text{The Amount of Wastewater Produced(t)}}{\text{Power Generation(tne thousand kWh)}}$$

Comprehensive Repeated Utilization Factor of Domestic Sewage: it is a measure of the production of domestic sewage generated after treatment, the amount of recycled water to produce the ratio of total domestic sewage.

$$\text{Comprehensive Repeated Utilization Factor of Domestic Sewage} = \frac{\text{Reuse of Domestic Sewage after Treatment}}{\text{Total Domestic Sewage}} \times 100\%$$

Comprehensive Repeated Utilization Factor of Industrial Wastewater: it is a measure of the ratio of industrial-use water used in the production of industrial water that has been treated and then reused as a percentage of industrial water.

$$\text{Comprehensive Repeated Utilization Factor of Industrial Wastewater} = \frac{\text{Reuse of Industrial Sewage after Treatmen}}{\text{Total Industrial Sewage}} \times 100\%$$

Comprehensive Utilization Factor of Desulfurization Gypsum: reflects the level of comprehensive utilization of gypsum produced by the enterprises in the production process, and indirectly reflects the degree of quantification of solid waste generated by enterprises.

$$\text{Comprehensive Utilization Factor of Desulfurization Gypsum} = \frac{\text{The Comprehensive Utilization of Gypsum}}{\text{The Amount of Gypsum}} \times 100\%$$

Comprehensive Utilization Factor of Coal Ash reflects the comprehensive utilization level of fly ash generated by the enterprises in the production process and indirectly reflects the quantification of solid waste generated by enterprises.

$$\text{Comprehensive Utilization Factor of Coal Ash} = \frac{\text{The Comprehensive Utilization of Fly Ash}}{\text{The Amount of Fly Ash}} \times 100\%$$

Comprehensive Utilization Factor of Bottom Ash: Reflect the level of comprehensive utilization of bottom slag generated in the production process, but also indirectly reflects the degree of quantification of solid waste generated by the enterprise.

$$\text{Comprehensive Utilization Factor of Bottom Ash} = \frac{\text{The Comprehensive Utilization of Bottom Slag}}{\text{The Amount of Bottom Slag}} \times 100\%$$

Table 5.10 Experts' score results of electric power enterprise index weight determination

Criterion Layer	Average Score	Indexes	Average Score
Economic Benefits	6.0	Growth Rate of Sales Revenue	5.0
		Net Return on Assets	5.8
		Economic Output Density	7.8
		Economic Benefits from the Implementation of Circular Economy	7.5
		Non-power Output Value Proportion	8.8
Resource & Energy Consumption	8.2	Standard Unit Coal Consumption for Power Generation	8.4
		Standard Unit Coal Consumption for Power Supply	8.0
		Water Consumption for Unit Product	5.8
		Comprehensive Station Service Power Consumption Rate	8.9
		Oil Consumption for Unit Product	5.5
		Energy Utilization Efficiency	4.2
		Annual Heat-to-electric Ratio	5.6
Waste Discharge	7.8	Standard Discharge Rate of Wastewater	4.8
		Standard Discharge Rate of Exhaust Gas	5.0
		Safe Disposal Rate of Hazardous Wastes	5.5
		Rate of Environmental Noise Reaching Standards	8.9
		Flue Dust Emission for Unit Product	8.2
		Sulfur Dioxide Emissions per unit Output Value	6.3
		Nitric Oxide Emission for Unit Product	6.0
		Ash Residue Production for Unit Product	8.7
		Wastewater Production for Unit Product	5.5
Recycle & Reuse	8.8	Comprehensive Repeated Utilization Factor of Domestic Sewage	6.6
		Comprehensive Repeated Utilization Factor of Industrial Wastewater	7.0
		Comprehensive Utilization Factor of desulfurization gypsum	8.2
		Comprehensive Utilization Factor of Coal Ash	8.0
		Comprehensive Utilization Factor of Bottom Ash	8.5
		Comprehensive Utilization Factor of Exhaust Heat	5.8
Environmental Protection Construction&Technological Innovation Capabilities	5	Rate of Enterprise Environmental Protection Investment	8.4
		Environmental Protection Equipment Proportion	7.0
		Innovation Input Capability	7.1
		Technological R&D Capability	8.3
		Ratio of Scientific and Technical Personnel	7.0
Enterprise Management & Social Benefits	5	Enterprise Circular Economy Knowledge Training	6.3
		Enterprise Circular Economy Norms Construction	6.0
		Enterprise Information System Construction	8.4
		Employee Awareness about Environmental Protection	8.8
		Enterprise Brand Value and Social Image	5.6

Table 5.11 Evaluation Index System for Circular Economy of Electric Power Enterprises

Criterion Layer	Indexes	Weights U
Economic Benefits 0.1173	Growth Rate of Sales Revenue	0.1094
	Net Return on Assets	0.1094
	Economic Output Density	0.2065
	Economic Benefits from the Implementation of Circular Economy	0.2065
	Non-power Output Value Proportion	0.3682
Resource & Energy Consumption 0.2031	Standard Unit Coal Consumption for Power Generation	0.2059
	Standard Unit Coal Consumption for Power Supply	0.2059
	Water Consumption for Unit Product	0.1072
	Comprehensive Station Service Power Consumption Rate	0.2059
	Oil Consumption for Unit Product	0.1072
	Energy Utilization Efficiency	0.0606
	Annual Heat-to-electric Ratio	0.1072
Waste Discharge 0.2031	Standard Discharge Rate of Wastewater	0.0545
	Standard Discharge Rate of Exhaust Gas	0.0545
	Safe Disposal Rate of Hazardous Wastes	0.0545
	Rate of Environmental Noise Reaching Standards	0.1799
	Flue Dust Emission for Unit Product	0.1799
	Sulfur Dioxide Emissions per unit Output Value	0.0990
	Nitric Oxide Emission for Unit Product	0.0990
	Ash Residue Production for Unit Product	0.1799
	Wastewater Production for Unit Product	0.0990
Recycle & Reuse 0.3383	Comprehensive Repeated Utilization Factor of Domestic Sewage	0.1205
	Comprehensive Repeated Utilization Factor of Industrial Wastewater	0.1205
	Comprehensive Utilization Factor of desulfurization gypsum	0.2298
	Comprehensive Utilization Factor of Coal Ash	0.2298
	Comprehensive Utilization Factor of Bottom Ash	0.2298
	Comprehensive Utilization Factor of Exhaust Heat	0.0696
Environmental Protection Construction & Technological Innovation Capabilities 0.0690	Rate of Enterprise Environmental Protection Investment	0.2857
	Environmental Protection Equipment Proportion	0.1429
	Innovation Input Capability	0.1429
	Technological R&D Capability	0.2857
	Ratio of Scientific and Technical Personnel	0.1429
Enterprise Management & Social Benefits 0.0690	Enterprise Circular Economy Knowledge Training	0.1429
	Enterprise Circular Economy Norms Construction	0.1429
	Enterprise Information System Construction	0.2857
	Employee Awareness about Environmental Protection	0.2857
	Enterprise Brand Value and Social Image	0.1429

5.2.2 Evaluation Index System of Steel Enterprise Circular Economy

(1)Iron and steel enterprises are characterized by long processes and many processes. They have many connections with the outside world in terms of products, resources and waste utilization during the production process and product consumption stage. With the progress of science and technology, such contacts and intersections are more closely linked. Therefore, in accordance with the concept of circular economy, with reduction, reuse and recycling as the guiding principle, and adhering to the scientific and technological progress, starting from the various links in production, the inter-departmental within enterprises and the inter-relationship between enterprises and the external environment, The exchange of energy and information, and the building of an eco-industrial chain with the iron and steel enterprises as the core are the inevitable trends for the steel industry to achieve sustainable development(Du Chunli, 2009).

(2) Based on the enterprise general circular economy evaluation index system and the characteristics of high energy consumption and high emission of the steel industry, the circular economy of the iron and steel enterprises Evaluation System. There are six aspects of the system standard layer, and the index layer specifically includes 37 evaluation indexes, as shown in Table6.9.

(3) Supplementary explanation of index meaning:

The Consumption of Mineral Resources per Unit of Steel: It is an index of the reduction of investment in the means of production of steel enterprises, which reflects the amount of mineral resources consumed per ton of steel produced. This index can described the iron and steel enterprises in the production process of mineral resources consumption.

$$\text{The Consumption of Mineral Resources per Unit of Steel} = \frac{\text{The Mineral Resources Input(t)}}{\text{Steel Production(t)}}$$

Comprehensive Energy Consumption per Unit of Steel: It is an index of the extent to which steel companies use less energy in the production process.

$$\text{Comprehensive Energy Consumption per Unit of Steel} = \frac{\text{Comprehensive Energy Consumption(t)}}{\text{Steel Production(t)}}$$

Fresh Water Consumption per Unit of Steel: It is an index to reflect the degree of water utilization in production process. Fresh water here refers to tap water that does not include reuse water and reuse water.

$$\text{Fresh Water Consumption per Unit of Steel} = \frac{\text{Fresh Water Consumption(m}^3\text{)}}{\text{Steel Production(t)}}$$

Recovered Iron Recycled Material Usage Rate: It is an index used to reflect the reduced capacity of steel enterprises to invest in materials, and indirectly reflects the level of reduction in the use of raw materials

$$\text{Recovered Iron Recycled Material Usage Rate} = \frac{\text{Recovered Iron Recycled Material Input}}{\text{Mineral Resources Input}} \times 100\%$$

Mineral Resources Utilization Efficiency: It refers to the production of a certain number of raw materials produced by the number of products, or the formation of product entities, the amount of raw materials accounted for the ratioof input. It is a reflection of the degree of utilization of mineral resources in iron and steel enterprises indexes. The higher degree of utilization indicates that more steel products can be produced by the same amount of mineral resources or less mineral resources can be produced by producing the same amount of steel products. It is a comprehensive reflection of enterprise production technology and management level.

$$\text{Mineral Resources Utilization Efficiency} = \frac{\text{The amount of mineral resources used to form steel products}}{\text{Mineral Resources Input}} \times 100\%$$

Wastewater Discharge per Unit of Steel: The ratio of the total amount of wastewater discharged during the production process to the total output of iron and steel enterprises can be used for pollutant reduction control.

$$\text{Wastewater Discharge per Unit of Steel} = \frac{\text{Wastewater Discharge }(t)}{\text{Steel Production(t)}}$$

Volatile Phenol Emissions per Unit of Steel: The ratio of the total amount of volatile phenol released in the production of steel enterprises to the total steel output of enterprises can be used for the reduction control of toxic pollutants.

$$\text{Volatile Phenol Emissions per Unit of Steel} = \frac{\text{Volatile Phenol Emissions(kg)}}{\text{Steel Production(t)}}$$

Cyanide Emissions per Unit of Steel: The ratio of the total amount of cyanide discharged in the production process of steel enterprises to the total output of iron and steel enterprises can be used to control the reduction of toxic pollutants.

$$\text{Cyanide Emissions per Unit of Steel} = \frac{\text{Cyanide Emissions(kg)}}{\text{Steel Production(t)}}$$

Exhaust Emissions per Unit of Steel: The ratio of the total amount of exhaust gas emitted by the iron and steel enterprises in the production process to the total steel output of enterprises reflects the emission of air pollutants from enterprises and can be used for the reduction of air pollutants.

$$\text{Exhaust Emissions per Unit of Steel} = \frac{\text{Exhaust Emissions}(\text{m}^3)}{\text{Steel Production(t)}}$$

Sulfur Dioxide Emissions per Unit of Steel: The ratio of the total amount of sulfur dioxide emitted by the iron and steel enterprises in the production process to the total steel output of the enterprises reflects the sulfur dioxide emission index and can be used for the control of the reduction of sulfur pollutants in the atmosphere.

$$\text{Sulfur Dioxide Emissions per Unit of Steel} = \frac{\text{Sulfur Dioxide Emissions}(\text{m}^3)}{\text{Steel Production(t)}}$$

Nitrogen Oxide Emissions per Unit of Steel: The ratio of the total amount of nitrogen oxides emitted by the iron and steel enterprises in the production process to the total steel output of the enterprises reflects the nitrogen oxide emission index and can be used for the reduction control of atmospheric nitrogen pollutants.

$$\text{Nitrogen Oxide Emissions per Unit of Steel} = \frac{\text{Nitrogen Oxide Emissions}(\text{m}^3)}{\text{Steel Production(t)}}$$

Solid Waste Emissions per Unit of Steel: The ratio of the total amount of solid waste generated in the production process of the iron and steel enterprises to the total steel output of the enterprise can be used to control the reduction of solid waste pollutants.

$$\text{Solid Waste Emissions per Unit of Steel} = \frac{\text{Solid Waste Emissions(t)}}{\text{Steel Production(t)}}$$

Heavy Metals and Radioactive Sludge Emissions per Unit of Steel: The ratio of the total amount of heavy metals and radioactive sludge produced in the production process of steel enterprises to the total steel output of enterprises can be used for the reduction control of harmful solid waste pollutants.

$$\begin{aligned}&\text{Heavy Metals and Radioactive Sludge Emissions per Unit of Steel}\\&= \frac{\text{Heavy Metals and Radioactive Sludge Emissions(t)}}{\text{Steel Production(t)}}\end{aligned}$$

Intermediate Byproduct Gas Recovery and Utilization Rate: It is an index that measures the ability of steel companies to recycle raw materials.

$$\begin{aligned}&\text{Intermediate Byproduct Gas Recovery and Utilization Rate}\\&= \frac{\text{Intermediate Byproduct Gas Recovery and Utilization}}{\text{Generated Intermediate Byproduct Gas}} \times 100\%\end{aligned}$$

Comprehensive Utilization of Iron-bearing Solid Waste in the Production Process: It reflects the level of comprehensive utilization of iron-containing solid waste (including scrap steel, iron skins, iron filings, etc.) generated by the iron and steel enterprises in the production process and indirectly reflects the quantification of the iron-containing solid waste generated by the enterprises.

$$\begin{aligned}&\text{Comprehensive Utilization of Iron - bearing Solid Waste in the Production Process}\\&= \frac{\text{Iron - bearing Solid Waste Utilization}}{\text{Generated Iron - bearing Solid Waste}} \times 100\%\end{aligned}$$

Waste Steel Products Recovery Rate: It is an index that reflects how much the steel industry recycles steel products that have been produced and sold.

$$\text{Waste Steel Products Recovery Rate} = \frac{\text{Waste Steel Products Recovery}}{\text{Generated Steel Products}} \times 100\%$$

Table 5.12 Experts' score results of steel enterprise index weight determination

Criterion Layer	Average Score	Indexes	Average Score
Economic Benefits	6.0	Growth Rate of Sales Revenue	5.0
		Net Return on Assets	5.2
		Economic Output Density	8.0
		Economic Benefits from the Implementation of Circular Economy	8.5
Resource & Energy Consumption	8.2	The Consumption of Mineral Resources per Unit of Steel	7.3
		Comprehensive Energy Consumption per Unit of Steel	7.5
		Fresh Water Consumption per Unit of Steel	7.1
		Enterprise Clean Energy Utilization Rate	5.2
		Recovered Iron Recycled Material Usage Rate	8.5
		Energy Utilization Efficiency	5.2
		Mineral Resources Utilization Efficiency	8.8
Waste Discharge	7.8	Standard Discharge Rate of Wastewater	5.3
		Standard Discharge Rate of Exhaust Gas	5.0
		Safe Disposal Rate of Hazardous Wastes	5.1
		Wastewater Discharge per Unit of Steel	7.3
		Volatile Phenol Emissions per Unit of Steel	8.5
		Cyanide Emissions per Unit of Steel	8.7
		Exhaust Emissions per Unit of Steel	7.2
		Sulfur Dioxide Emissions per Unit of Steel	7.0
		Nitrogen Oxide Emissions per Unit of Steel	8.5
		Solid Waste Emissions per Unit of Steel	7.3
		Heavy Metals and Radioactive Sludge Emissions per Unit of Steel	8.8
Recycle & Reuse	8.8	Intermediate Byproduct Gas Recovery and Utilization Rate	6.3
		Wastewater Comprehensive Utilization Rate	5.3
		Comprehensive Utilization of Iron-bearing Solid Waste in the Production Process	9.0
		Waste Steel Products Recovery Rate	6.5
		Waste Heat Utilization Rate	8.8
Environmental Protection Construction & Technological Innovation Capabilities	5	Rate of Enterprise Environmental Protection Investment	8.4
		Environmental Protection Equipment Proportion	6.2
		Innovation Input Capability	6.3
		Technological R&D Capability	8.0
		Ratio of Scientific and Technical Personnel	6.5
Enterprise Management & Social Benefits	5	Enterprise Circular Economy Knowledge Training	6.3
		Enterprise Circular Economy Norms Construction	6.0
		Enterprise Information System Construction	8.4
		Employee Awareness about Environmental Protection	8.5
		Enterprise Brand Value and Social Image	6.2

Table 5.13 Steel enterprises circular economy evaluation index system

Criterion Layer	Indexes	Weights U
Economic Benefits 0.1173	Growth Rate of Sales Revenue	0.1667
	Net Return on Assets	0.1667
	Economic Output Density	0.3333
	Economic Benefits from the Implementation of Circular Economy	0.3333
Resource & Energy Consumption 0.2031	The Consumption of Mineral Resources per Unit of Steel	0.1287
	Comprehensive Energy Consumption per Unit of Steel	0.1287
	Fresh Water Consumption per Unit of Steel	0.1287
	Enterprise Clean Energy Utilization Rate	0.0698
	Recovered Iron Recycled Material Usage Rate	0.2371
	Energy Utilization Efficiency	0.0698
	Mineral Resources Utilization Efficiency	0.2371
Waste Discharge 0.2031	Standard Discharge Rate of Wastewater	0.0425
	Standard Discharge Rate of Exhaust Gas	0.0425
	Safe Disposal Rate of Hazardous Wastes	0.0425
	Wastewater Discharge per Unit of Steel	0.0766
	Volatile Phenol Emissions per Unit of Steel	0.1416
	Cyanide Emissions per Unit of Steel	0.1416
	Exhaust Emissions per Unit of Steel	0.0766
	Sulfur Dioxide Emissions per Unit of Steel	0.0766
	Nitrogen Oxide Emissions per Unit of Steel	0.1416
	Solid Waste Emissions per Unit of Steel	0.0766
	Heavy Metals and Radioactive Sludge Emissions per Unit of Steel	0.1416
Recycle & Reuse 0.3383	Intermediate Byproduct Gas Recovery and Utilization Rate	0.1578
	Wastewater Comprehensive Utilization Rate	0.0885
	Comprehensive Utilization of Iron-bearing Solid Waste in the Production Process	0.2979
	Waste Steel Products Recovery Rate	0.1578
	Waste Heat Utilization Rate	0.2979
Environmental Protection Construction & Technological Innovation Capabilities 0.0690	Rate of Enterprise Environmental Protection Investment	0.2857
	Environmental Protection Equipment Proportion	0.1429
	Innovation Input Capability	0.1429
	Technological R&D Capability	0.2857
	Ratio of Scientific and Technical Personnel	0.1429
Enterprise Management & Social Benefits 0.0690	Enterprise Circular Economy Knowledge Training	0.1429
	Enterprise Circular Economy Norms Construction	0.1429
	Enterprise Information System Construction	0.2857
	Employee Awareness about Environmental Protection	0.2857
	Enterprise Brand Value and Social Image	0.1429

5.2.3 Evaluation Index System of Coal Enterprise Circular Economy

(1) General large-scale coal resources recycling program for the enterprise: coal mine drainage process using coal washing, closed-loop washing cycle and zero discharge. Some coal mines have large displacement and can be used for power generation cooling or other industrial projects after simple purification except for coal washing(Zhang Kai, 2009). The coal and gangue discharged from the coal washing process use the circulating fluidized bed boiler to generate electricity or heat for power supply and heating for industrial production and residential life in the whole park. Coal gangue, fly ash and power plant slag and other industrial waste to produce cement, blocks, bricks and other building materials, or as paving materials, filling waste mines and so on(Wang Linzhu, 2013).

(2) Based on the construction of general circular economy evaluation index system of enterprises, combined with the characteristics of high exploitation and resource consumption in coal industry (Sun Lei, 2007; Xu Jun, 2011; Yan Bohua, 2007), referring to the development model of circular economy of typical enterprises, Circular Economy Evaluation Index System for Coal Enterprises with Characteristic Indexes. There are six aspects of the system guideline, and the index level is specifically 39 indexes, as shown in Table6.10.

(3) Supplementary explanation of index meaning:

The Ratio of Non-coal Output Value: It is an index used to measure the comprehensive development of coal enterprises economic ability. In addition to the coal output value of enterprises, other comprehensive development and diversified operations to bring the output value of the ratioof total output value.

$$\text{The Ratio of Non-coal Output Value} = \frac{\text{The Non-coal Output Value}}{\text{The Total Output Value}} \times 100\%$$

Raw Material Consumption per Unit Output Value: it is a measure of the coal enterprises to reduce the input of means of production of index; the index reflects the output value of 10,000 yuan caused by ore consumption of raw materials. To illustrates the enterprise resource consumption in the production process.

$$\text{Raw Material Consumption per Unit Output Value} = \frac{\text{Raw Material Consumption(t)}}{\text{Total Output Value(ten thousand yuan)}}$$

Reserve Production Ratio: the ratio of coal recoverable reserves to annual output reflects the status of coal resources and the number of years available for mining.

$$\text{Reserve Production Ratio} = \frac{\text{Coal recoverable stock(t)}}{\text{Coal Mining(t)}} \times 100\%$$

Mining Recovery Rate: it it refers to the ratioof the total mineral when the mine is mined for the second time, meaning that the recoverable mines have been mined for the second time.

$$\text{Mining Recovery Rate} = \frac{\text{Mining Coal}}{\text{Coal Reserves}} \times 100\%$$

Washing Rate of Raw Coal: it reflects the coal quality.

$$\text{Washing Rate of Raw Coal} = \frac{\text{Wash Coal Volume}}{\text{Mined Raw Coal Volume}} \times 100\%$$

Flue Dust Emission for Unit Output Value: The ratio of the total amount of soot and dust emissions to the total output value of enterprises in the production process reflects the emission of particulate matter from dust and dust in the air pollutants of the enterprise and can be used to control the reduction of atmospheric particulate pollutants.

$$\text{Flue Dust Emission for Unit Output Value} = \frac{\text{Flue Dust Emission}(m^3)}{\text{Total Output Value(ten thousand yuan)}}$$

Comprehensive Utilization Rate of Mine Water: it is used to reflect the coal enterprises in the production process of mine water produced by the comprehensive utilization level.

$$\text{Comprehensive Utilization Rate of Mine Water} = \frac{\text{Comprehensive Utilization of Mine Water}}{\text{Genetated Mine Water}} \times 100\%$$

Coal Recycling Water Ratio: It is used to reflect the level of recycled coal produced by the enterprise during the production process.

$$\text{Coal Recycling Water Ratio} = \frac{\text{Recycling Water}}{\text{Water Utilization}} \times 100\%$$

Comprehensive Utilization Rate of Coal Gangue: It is used to reflect the comprehensive utilization of coal gangue produced in the production process.

$$\text{Comprehensive Utilization Rate of Coal Gangue} = \frac{\text{Comprehensive Utilization of Coal Gangue}}{\text{Generated Coal Gangue}} \times 100\%$$

Comprehensive Utilization of Coalbed Methane: Reflects the enterprise on the production process of coal bed methane generated by the comprehensive utilization level.

$$\text{Comprehensive Utilization Rate of Coalbed Methane} = \frac{\text{Comprehensive Utilization of Coalbed Methane}}{\text{The Amount of Coalbed Methane}} \times 100\%$$

Collapse Land Reclamation Rate: It reflects the level of enterprises in repairing and reclaiming land destroyed in the production process.

$$\text{Collapse Land Reclamation Rate} = \frac{\text{Collapse Land Reclamation}}{\text{The Total Area Destroyed by Mining Land}} \times 100\%$$

Associated Mineral Development and Utilization: It is used to reflect the capacity of coal mines to exploit the associated minerals in the coal mining process.

$$\text{Associated Mineral Development and Utilization} = \frac{\text{Associated Mineral Utilization}}{\text{Species Number of Associated Mineral}} \times 100\%$$

The Number of Deaths per Unit Production: The number of deaths per million tons of coal produced by coal mining enterprises reflects the degree of safety in production of enterprises and their responsibilities to employees and to the society. To protect people's safety and reduce the number of deaths is the primary criterion that coal enterprises should follow.

$$\text{The Number of Deaths per Unit Production} = \frac{\text{The Number of Deaths } (-)}{\text{Coal Production (million tons)}}$$

Table 5.14 Experts' score results of coal enterprise index weight determination

Criterion Layer	Average Score	Indexes	Average Score
Economic Benefits	6.0	Growth Rate of Sales Revenue	6.8
		Net Return on Assets	6.5
		Economic Output Density	8.0
		The Ratio of Non-coal Output Value	9.6
		Economic Benefits from the Implementation of Circular Economy	8.2
Resource & Energy Consumption	8.2	Raw Material Consumption per Unit Output Value	7.8
		Comprehensive Energy Consumption Per Unit Output Value	4.6
		Fresh Water Consumption Per Unit Output Value	5.0
		Reserve Production Ratio	8.9
		Mining Recovery Rate	9.2
		Washing Rate of Raw Coal	9.5
Waste Discharge	7.8	Standard Discharge Rate of Wastewater	5.6
		Standard Discharge Rate of Exhaust Gas	5.8
		Safe Disposal Rate of Hazardous Wastes	5.5
		Rate of Environmental Noise Reaching Standards	5.5
		Wastewater Discharge Per Ten Thousand Yuan Output Value	8.5
		Exhaust Emissions Per Ten Thousand Yuan Output Value	7.4
		Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	7.6
		Flue Dust Emission for Unit Output Value	8.7
		Solid Waste Emission Per Ten Thousand Yuan Output Value	8.8
Recycle & Reuse	8.8	Solid Waste Comprehensive Utilization Rate	5.3
		Comprehensive Utilization Rate of Mine Water	9.1
		Coal Recycling Water Ratio	6.0
		Comprehensive Utilization Rate of Coal Gangue	8.8
		Comprehensive Utilization Factor of Coal Ash	6.2
		Comprehensive Utilization of Coalbed Methane	9.0
		Collapse Land Reclamation Rate	6.4
		Associated Mineral Development and Utilization	6.5
Environmental Protection Construction & Technological Innovation Capabilities	5	Rate of Enterprise Environmental Protection Investment	8.9
		Environmental Protection Equipment Proportion	7.6
		Innovation Input Capability	7.0
		Technological R&D Capability	9.2
		Ratio of Scientific and Technical Personnel	7.8
Enterprise Management & Social Benefits	5	The Number of Deaths per Unit Production	8.7
		Enterprise Circular Economy Knowledge Training	7.5
		Enterprise Circular Economy Norms Construction	7.0
		Enterprise Information System Construction	9.2
		Employee Awareness about Environmental Protection	9.5
		Enterprise Brand Value and Social Image	6.8

Table 5.15 circular economy evaluation index system of coal enterprises

Criterion Layer	Indexes	Weights U
Economic Benefits 0.1173	Growth Rate of Sales Revenue	0.1094
	Net Return on Assets	0.1094
	Economic Output Density	0.2065
	The Ratio of Non-coal Output Value	0.3682
	Economic Benefits from the Implementation of Circular Economy	0.2065
Resource & Energy Consumption 0.2031	Raw Material Consumption per Unit Output Value	0.1315
	Comprehensive Energy Consumption Per Unit Output Value	0.0759
	Fresh Water Consumption Per Unit Output Value	0.0759
	Reserve Production Ratio	0.2389
	Mining Recovery Rate	0.2389
	Washing Rate of Raw Coal	0.2389
Waste Discharge 0.2031	Standard Discharge Rate of Wastewater	0.0580
	Standard Discharge Rate of Exhaust Gas	0.0580
	Safe Disposal Rate of Hazardous Wastes	0.0580
	Rate of Environmental Noise Reaching Standards	0.0580
	Wastewater Discharge Per Ten Thousand Yuan Output Value	0.1856
	Exhaust Emissions Per Ten Thousand Yuan Output Value	0.1055
	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	0.1055
	Flue Dust Emission for Unit Output Value	0.1856
	Solid Waste Emission Per Ten Thousand Yuan Output Value	0.1856
Recycle & Reuse 0.3383	Solid Waste Comprehensive Utilization Rate	0.0538
	Comprehensive Utilization Rate of Mine Water	0.1865
	Coal Recycling Water Ratio	0.0967
	Comprehensive Utilization Rate of Coal Gangue	0.1865
	Comprehensive Utilization Factor of Coal Ash	0.0967
	Comprehensive Utilization of Coalbed Methane	0.1865
	Collapse Land Reclamation Rate	0.0967
	Associated Mineral Development and Utilization	0.0967
Environmental Protection Construction &Technological Innovation Capabilities 0.0690	Rate of Enterprise Environmental Protection Investment	0.2857
	Environmental Protection Equipment Proportion	0.1429
	Innovation Input Capability	0.1429
	Technological R&D Capability	0.2857
	Ratio of Scientific and Technical Personnel	0.1429
Enterprise Management & Social Benefits 0.0690	The Number of Deaths per Unit Production	0.2222
	Enterprise Circular Economy Knowledge Training	0.1111
	Enterprise Circular Economy Norms Construction	0.1111
	Enterprise Information System Construction	0.2222
	Employee Awareness about Environmental Protection	0.2222
	Enterprise Brand Value and Social Image	0.1111

5.2.4 Evaluation Index System of Papermaking Enterprise Circular Economy

(1) The black liquor produced in the pulping process can be recycled after the evaporation and combustion process. On the one hand, it is used in the pulping process, on the other hand it can be used for power generation and heating, for energy recovery, and then for pulping and papermaking processes. In addition, the black liquor produced by the evaporation and combustion of green liquor, after caustic and lime calcination process, can produce white liquid, alkali recovery, and then for the pulp process. In addition, lignin can also be extracted by acid analysis(Wang Qiuyun, 2007). At the same time, white water from the papermaking process can also be recycled for the pulping process. Sludge produced by papermaking can be used as organic fertilizer after processing. Waste paper used by paper products is recycled through the waste recycling market and sorted and processed, and then re-enters the manufacturing process as a pulping raw material to form a loop(Zhu Li, 2008). Wood processing enterprises processing residue, after processing can be used as raw material for pulping.

(2) Based on the evaluation index system of general circular economy of the enterprise and combining with the characteristics of large papermaking industry, such as large energy consumption, large water consumption and serious pollution(Yao Huifang, 2012;Chen Fan, 2008; Wang Haishan, 2013; Wang Chunhua, 2013; Wang Qiuyun, 2013; Liu Lei, 2009; Wu Donggang, 2007; Li Zhongzheng,2008), referring to the development model of circular economy of typical enterprises, Papermaking enterprises circular economy evaluation index system. The system is divided into six layers of guidelines, the index level specifically 35 evaluation indexes, see Table6.11.

(3) Supplementary explanation of index meaning:

Fiber Raw Materials Consumption per Unit Paper Production: It is a measure of the reduction of investment in the means of production of papermaking enterprises. This index reflects the consumption of fiber materials per ton of paper, including wood, bagasse and waste paper. It shows the degree of resource consumption in the production process.

$$\text{Fiber Raw Materials Consumption per Unit Paper Production} = \frac{\text{Fiber Raw Materials Input(t)}}{\text{Paper Production(t)}}$$

Comprehensive Energy Consumption per Unit of paper: It is an index used to reflect the degree of energy reduction in the papermaking enterprises in the production process,

$$\text{Comprehensive Energy Consumption per Unit of paper} = \frac{\text{Comprehensive Energy Consumption(t)}}{\text{Paper Production(t)}}$$

Fresh Water Consumption per Unit of paper production: It is an index reflecting the degree of utilization of water resources by paper-making enterprises. Fresh water here refers to tap water that does not include reuse water and reuse water.

$$\text{Fresh Water Consumption per Unit of paper production} = \frac{\text{Fresh Water Consumption } (m^3)}{\text{Paper Production(t)}}$$

Recycled Materials Rate in Raw Materials: It is used to reflect the capacity of papermaking enterprises to reduce the use of materials, but also indirectly reflects the reduction of raw materials into use.

$$\text{Recycled Materials Rate in Raw Materials} = \frac{\text{Recycled Materials Input}}{\text{Raw Materials Input}} \times 100\%$$

Raw Material Utilization Efficiency: It refers to how many pieces of paper product are produced from a certain amount of fiber material put into the production process or the ratioof the fiber material forming the paper product entity to the input amount. It is an index of the degree of utilization of raw materials. The higher the degree of utilization, the same amount of raw materials can be produced to produce more products, or produce the same amount of product can consume less raw materials. It is a comprehensive reflection of enterprise production technology and management level.

$$\text{Raw Material Utilization Efficiency} = \frac{\text{The amount of mineral resources used to form paper products}}{\text{Raw Material Input}} \times 100\%$$

Wastewater Discharge per Unit of Paper Production: Papermaking enterprises in the production process of waste water discharged and the ratio of enterprise paper production, can be used for pollutant reduction control.

$$\text{Wastewater Discharge per Unit of Paper Production} = \frac{\text{Wastewater Discharge}\,(m^3)}{\text{Paper Production}\,(t)}$$

COD Emissions per Unit of Paper Production: Papermaking enterprises in the production process of COD emissions and corporate paper production ratio, can be used for organic pollutant reduction control.

$$\text{COD Emissions per Unit of Paper Production} = \frac{\text{COD Emissions}\,(kg)}{\text{Paper Production}\,(t)}$$

Exhaust Emissions per Unit of Paper Production: The ratio of the total amount of exhaust gas discharged during the production of papermaking enterprises to the production volume of enterprise paper can be used for the reduction control of air pollutants.

$$\text{Exhaust Emissions per Unit of Paper Production} = \frac{\text{Exhaust Emissions}\,(m^3)}{\text{Paper Production}\,(t)}$$

Dust Emissions per Unit of Paper Production: Paper manufacturing enterprises in the process of emissions of dust and corporate paper production ratio can be used for air pollutants reduction of particulate matter control.

$$\text{Dust Emissions per Unit of Paper Production} = \frac{\text{Dust Emissions}\,(t)}{\text{Paper Production}\,(t)}$$

Sulfur Dioxide Emissions per Unit of Paper Production: The ratio of the total amount of sulfur dioxide and paper produced by the enterprise during the production process can be used to control the reduction of atmospheric sulfur pollutants.

$$\text{Sulfur Dioxide Emissions per Unit of Paper Production} = \frac{\text{Sulfur Dioxide Emissions}\,(m^3)}{\text{Paper Production}\,(t)}$$

Solid Waste Emissions per Unit of Paper Production: The ratio of the total amount of solid waste generated in the production process of papermaking enterprises to the paper output of enterprises can be used for the reduction control of solid waste pollutants.

$$\text{Solid Waste Emissions per Unit of Paper Production} = \frac{\text{Solid Waste Emissions (t)}}{\text{Paper Production (t)}}$$

Alkali Recovery Rate: It is an index that is used to measure the reduction of alkali used in the papermaking industry. The higher the alkali recovery rate, the lower the amount of chemical materials, such as thenardite, put into the production process.

$$\text{Alkali Recovery Rate} = \frac{\text{Recovery Alkali Production} - \text{Supplement Alkali Production}}{\text{The Amount of Used Alkali}} \times 100\%$$

Waste Paper Products Comprehensive Utilization Rate: it is used to measure the level of recovery of waste paper produced by the paper industry. Waste paper can be used as a renewable resource for the production of paper-making enterprises. Recycling waste paper can reduce the emission of pollutants and reduce the input of raw materials for production.

$$\text{Waste Paper Products Comprehensive Utilization Rate} = \frac{\text{Recycled Waste Paper Product}}{\text{Paper Production}} \times 100\%$$

White Mud Comprehensive Utilization Rate: It is used to measure the level of comprehensive utilization of white clay produced by the paper industry.

$$\text{White Mud Comprehensive Utilization Rate} = \frac{\text{White Mud Comprehensive Utilization}}{\text{Generated White Mud}} \times 100\%$$

Table 5.16 Experts' score results of papaermaking enterprise index weight determination

Criterion Layer	Average Score	Indexes	Average Score
Economic Benefits	6.0	Growth Rate of Sales Revenue	6.3
		Net Return on Assets	6.0
		Economic Output Density	8.3
		Economic Benefits from the Implementation of Circular Economy	8.6
Resource & Energy Consumption	8.2	Fiber Raw Materials Consumption per Unit Paper Production	9.0
		Comprehensive Energy Consumption per Unit of Paper	7.4
		Fresh Water Consumption per Unit of Paper	7.8
		Enterprise Clean Energy Utilization Rate	6.0
		Recycled Materials Rate in Raw Materials	7.3
		Raw Material Utilization Efficiency	8.9
Waste Discharge	7.8	Standard Discharge Rate of Wastewater	6.7
		Standard Discharge Rate of Exhaust Gas	7.2
		Safe Disposal Rate of Hazardous Wastes	6.4
		Wastewater Discharge per Unit of Paper	7.0
		COD Emissions per Unit of Paper	8.9
		Exhaust Emissions per Unit of Paper	7.3
		Dust Emissions per Unit of Paper	8.5
		Sulfur Dioxide Emissions per Unit of Paper	6.5
		Solid Waste Emissions per Unit of Paper	8.4
Recycle & Reuse	8.8	Alkali Recovery Rate	7.5
		Wastewater Comprehensive Utilization Rate	7.2
		Solid Waste Comprehensive Utilization Rate	7.3
		Waste Paper Products Comprehensive Utilization Rate	8.3
		White Mud Comprehensive Utilization Rate	8.3
		Waste Heat Utilization Rate	7.0
Environmental Protection Construction &Technological Innovation Capabilities	5	Rate of Enterprise Environmental Protection Investment	8.3
		Environmental Protection Equipment Proportion	6.7
		Innovation Input Capability	6.0
		Technological R&D Capability	8.9
		Ratio of Scientific and Technical Personnel	6.5
Enterprise Management & Social Benefits	5	Enterprise Circular Economy Knowledge Training	6.7
		Enterprise Circular Economy Norms Construction	6.8
		Enterprise Information System Construction	8.9
		Employee Awareness about Environmental Protection	9.0
		Enterprise Brand Value and Social Image	7.0

Table 5.17 Evaluation index system of papermaking enterprises

Criterion Layer	Indexes	Weights U
Economic Benefits 0.1173	Growth Rate of Sales Revenue	0.1667
	Net Return on Assets	0.1667
	Economic Output Density	0.3333
	Economic Benefits from the Implementation of Circular Economy	0.3333
Resource & Energy Consumption 0.2031	Fiber Raw Materials Consumption per Unit Paper Production	0.2589
	Comprehensive Energy Consumption per Unit of Paper	0.1358
	Fresh Water Consumption per Unit of Paper	0.1358
	Enterprise Clean Energy Utilization Rate	0.0747
	Recycled Materials Rate in Raw Materials	0.1358
	Raw Material Utilization Efficiency	0.2589
Waste Discharge 0.2031	Standard Discharge Rate of Wastewater	0.0545
	Standard Discharge Rate of Exhaust Gas	0.0545
	Safe Disposal Rate of Hazardous Wastes	0.0545
	Wastewater Discharge per Unit of Paper	0.0990
	COD Emissions per Unit of Paper	0.1799
	Exhaust Emissions per Unit of Paper	0.0990
	Dust Emissions per Unit of Paper	0.1799
	Sulfur Dioxide Emissions per Unit of Paper	0.0990
	Solid Waste Emissions per Unit of Paper	0.1799
Recycle & Reuse 0.3383	Alkali Recovery Rate	0.2298
	Wastewater Comprehensive Utilization Rate	0.1205
	Solid Waste Comprehensive Utilization Rate	0.1205
	Waste Paper Products Comprehensive Utilization Rate	0.2298
	White Mud Comprehensive Utilization Rate	0.2298
	Waste Heat Utilization Rate	0.0696
Environmental Protection Construction &Technological Innovation Capabilities 0.0690	Rate of Enterprise Environmental Protection Investment	0.2857
	Environmental Protection Equipment Proportion	0.1429
	Innovation Input Capability	0.1429
	Technological R&D Capability	0.2857
	Ratio of Scientific and Technical Personnel	0.1429
Enterprise Management & Social Benefits 0.0690	Enterprise Circular Economy Knowledge Training	0.1429
	Enterprise Circular Economy Norms Construction	0.1429
	Enterprise Information System Construction	0.2857
	Employee Awareness about Environmental Protection	0.2857
	Enterprise Brand Value and Social Image	0.1429

5.3 A Case Study of Enterprise Circular Economy

5.3.1 Enterprise Introduction

Tianjin SDIC Jinneng Electric Power Co., Ltd. (also called Beijiang Electric Power Plant) constructed6×1000MW coal-fired power generation ultra-supercritical units and 600,000 tons/day sea water desalination devices. The Beijiang Electric Power Plant circular economy project adopts the circular economy model, and this model is divided into 5 subprojects: power generation, sea water desalination, salt-making from concentrated sea water, land-saving and consolidation and resource utilization of wastes (Yu, H. et al., 2011).

With the full operation of the Beijiang Electric Power Plant circular economy project, every year, 11 billion KWH of electricity, 65.7 million tons of fresh water, newly-added 0.5 million tons of crude salt, over 1 million cubic meter of environmental protection building materials, and 22 sq.km. of building land will be conserved. Resource recycle, energy cascade utilization, and the resource utilization of wastes will be completely achieved. Therefore, it is a typical circular economy project: resource-saving, environment-friendly, and low-carbon economy project. The material flow graph of circular economy is shown in Figure3. The details of the five circular economy sub-projects are as follows:(Yu et al., 2011; Wang et al., 2008)

(1) Power generation project

The main input material is crude coal, and the main output product is electricity, and the byproducts include waste heat and coal ash, etc.

(2) Seawater desalination project

The main inputs are the waste heat and raw seawater. The main outputs are brackish water and concentrated seawater.

(3) Salt-making from Concentrated Sea Water.

The main input is the concentrated sea water discharged from the sea water desalination project. The main output products are crude salt and saline chemical products.

(4) Land Saving and Consolidation

Because that the concentration of concentrated seawater is nearly double than raw sea water, 22sq.km.square kilometer saltern were saved.

(5) Resource utilization of Wastes

Its main inputs are the byproducts generated from the power project (e.g., coal ash and desulfurization gypsum), and the main outputs are building materials.

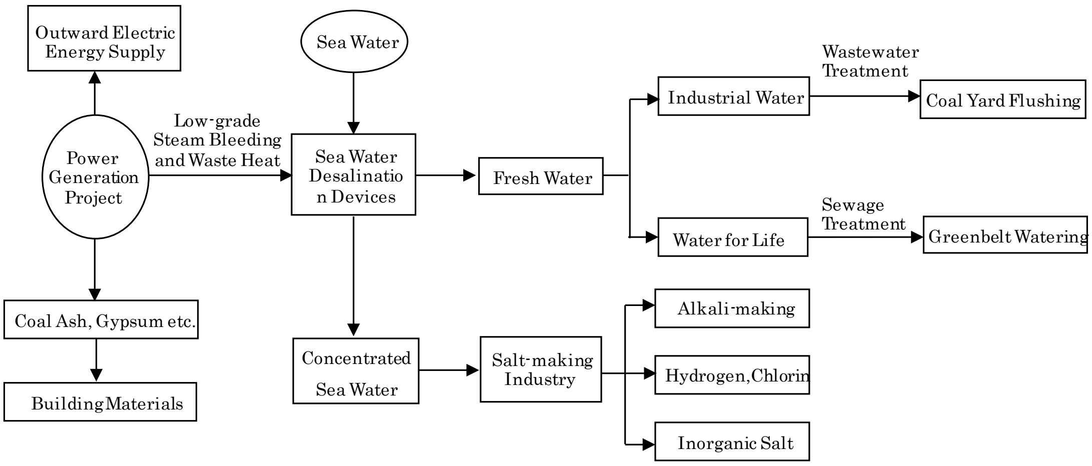

Figure 5.1 Material Flow Graph of Beijiang Electric Power Plant Circular Economy

5.3.2 Evaluation of Power Enterprise Circular Economy

5.3.2.1 Fuzzy Comprehensive Evaluation Factor Set

According to the established power enterprise circular economy evaluation index system, the target layer and the index layer factor set are:

$U=(U_1, U_2, U_3, U_4, U_5, U_6)$

$U_1=(U_{11}, U_{12}, U_{13}, U_{14}, U_{15})$

$U_2=(U_{21}, U_{22}, U_{23}, U_{24}, U_{25}, U_{26}, U_{27})$

$U_3=(U_{31}, U_{32}, U_{33}, U_{34}, U_{35}, U_{36}, U_{37}, U_{38}, U_{39})$

$U_4=(U_{41}, U_{42}, U_{43}, U_{44}, U_{45}, U_{46})$

$U_5=(U_{51}, U_{52}, U_{53}, U_{54}, U_{55})$

$U_6=(U_{61}, U_{62}, U_{63}, U_{64}, U_{65})$

Refer to Table 4.26 & 6.9 for index meanings.

5.3.2.2 Determination of Comprehensive Evaluation Matrix

Firstly, to determine the evaluation set of comprehensive evaluation V={excellent, good, fair, poor} or {very satisfactory, satisfactory, basically satisfactory, not satisfactory}.

Secondly, the questionnaire survey and expert scoring method was used to rate the implemented effect of Beijiang Electric Power Plant circular economy. Table 6.18 is the summarized results of questionnaires sent to ten relevant experts.

According to the above investigation and statistical result, the judgment matrix for each index layer as follows was determined. R_1~R_6 separately refer to the judgment matrix of economic benefits, resource & energy consumption, waste discharge, recycle & reuse, environmental protection construction & technological innovation capabilities, and enterprise management & social benefits.

$$R_1=\begin{bmatrix}0.5 & 0.4 & 0.1 & 0\\ 0.6 & 0.4 & 0 & 0\\ 0.6 & 0.3 & 0.1 & 0\\ 0.5 & 0.4 & 0.1 & 0\\ 0.6 & 0.3 & 0.1 & 0\end{bmatrix},\ R_2=\begin{bmatrix}0.8 & 0.2 & 0 & 0\\ 0.7 & 0.3 & 0 & 0\\ 0.6 & 0.3 & 0.1 & 0\\ 0.8 & 0.2 & 0 & 0\\ 0.7 & 0.2 & 0.1 & 0\\ 0.7 & 0.3 & 0 & 0\\ 0.6 & 0.3 & 0.1 & 0\end{bmatrix}$$

$$R_3=\begin{bmatrix}1 & 0 & 0 & 0\\ 1 & 0 & 0 & 0\\ 1 & 0 & 0 & 0\\ 1 & 0 & 0 & 0\\ 0.7 & 0.2 & 0.1 & 0\\ 0.8 & 0.2 & 0 & 0\\ 0.8 & 0.1 & 0.1 & 0\\ 0.7 & 0.3 & 0 & 0\\ 0.7 & 0.2 & 0.1 & 0\end{bmatrix},R_4=\begin{bmatrix}0.9 & 0.1 & 0 & 0\\ 0.9 & 0.1 & 0 & 0\\ 1 & 0 & 0 & 0\\ 1 & 0 & 0 & 0\\ 1 & 0 & 0 & 0\\ 0.9 & 0.1 & 0 & 0\end{bmatrix}$$

$$R_5=\begin{bmatrix}0.8 & 0.2 & 0 & 0\\ 0.7 & 0.2 & 0.1 & 0\\ 0.8 & 0.2 & 0 & 0\\ 0.7 & 0.3 & 0 & 0\\ 0.8 & 0.2 & 0 & 0\end{bmatrix},R_6=\begin{bmatrix}0.7 & 0.2 & 0.1 & 0\\ 0.8 & 0.1 & 0.1 & 0\\ 0.8 & 0.2 & 0 & 0\\ 0.7 & 0.2 & 0.1 & 0\\ 0.9 & 0.1 & 0 & 0\end{bmatrix}$$

Table 5.18 Summary of Investigation of the Implemented Effect of Beijiang Electric Power Plant Circular Economy

Item	Index	Excellent	Good	Fair	Poor
Economic Benefits U_1	Growth Rate of Sales Revenue	50%	40%	10%	0%
	Net Return on Assets	60%	40%	0%	0%
	Economic Output Density	60%	30%	10%	0%
	Economic Benefits from the Implementation of Circular Economy	50%	40%	10%	0%
	Non-power Output Value Proportion	60%	30%	10%	0%
Resource & Energy Consumption U_2	Standard Unit Coal Consumption for Power Generation	80%	20%	0%	0%
	Standard Unit Coal Consumption for Power Supply	70%	30%	0%	0%
	Water Consumption for Unit Product	60%	30%	10%	0%
	Comprehensive Station Service Power Consumption Rate	80%	20%	0%	0%
	Oil Consumption for Unit Product	70%	20%	10%	0%
	Energy Utilization Efficiency	70%	30%	0%	0%
	Annual Heat-to-electric Ratio	60%	30%	10%	0%
Waste Discharge U_3	Standard Discharge Rate of Wastewater	100%	0%	0%	0%
	Standard Discharge Rate of Exhaust Gas	100%	0%	0%	0%
	Safe Disposal Rate of Hazardous Wastes	100%	0%	0%	0%
	Rate of Environmental Noise Reaching Standards	100%	0%	0%	0%
	Flue Dust Emission for Unit Product	70%	20%	10%	0%
	Sulfur Dioxide Emission for Unit Product	80%	20%	0%	0%
	Nitric Oxide Emission for Unit Product	80%	10%	10%	0%
	Ash Residue Production for Unit Product	70%	30%	0%	0%
	Wastewater Production for Unit Product	70%	20%	10%	0%
Recycle & Reuse U_4	Comprehensive Repeated Utilization Factor of Domestic Sewage	90%	10%	0%	0%
	Comprehensive Repeated Utilization Factor of Industrial Wastewater	90%	10%	0%	0%
	Comprehensive Utilization Factor of Desulfurization Gypsum	100%	0%	0%	0%
	Comprehensive Utilization Factor of Coal Ash	100%	0%	0%	0%
	Comprehensive Utilization Factor of Bottom Ash	100%	0%	0%	0%
	Comprehensive Utilization Factor of Exhaust Heat	90%	10%	0%	0%
Environmental Protection Construction & Technological Innovation Capabilities U_5	Rate of Enterprise Environmental Protection Investment	80%	20%	0%	0%
	Enterprise Eco-environmental Transformation Potentials	70%	20%	10%	0%
	Innovation Input Capability	80%	20%	0%	0%
	Technological R&D Capability	70%	30%	0%	0%
	Ratioof Scientific and Technical Personnel	80%	20%	0%	0%
Enterprise Management & Social Benefits U_6	Enterprise Circular Economy Knowledge Training	70%	20%	10%	0%
	Enterprise Circular Economy Norms Construction	80%	10%	10%	0%
	Enterprise Information System Construction	80%	20%	0%	0%
	Employee Awareness about Environmental Protection	70%	20%	10%	0%
	Enterprise Brand Value and Social Image	90%	10%	0%	0%

5.3.2.3 Determination of Weight

By determining the weighted value of the power enterprise circular economy evaluation index (see Table 6.11), construct the index weight set A, A_1, A_2, A_3, A_4, A_5, A_6, specifically,

A=(0.1173, 0.2031, 0.2031,0.3383,0.0690,0.0690)

A_1=(0.1094, 0.1094,0.2065,0.2065,0.3682)

A_2=(0.2059, 0.2059, 0.1072, 0.2059, 0.1072, 0.0606, 0.1072)

A_3=(0.0545,0.0545,0.0545, 0.1799, 0.1799, 0.0990, 0.0990, 0.1799, 0.0990)

A_4=(0.1205, 0.1205, 0.2298, 0.2298, 0.2298, 0.0696)

A_5=(0.2857, 0.1429, 0.1429, 0.2857, 0.1429)

A_6=(0.1429, 0.1429, 0.2857, 0.2857, 0.1429)

A represents the index weight set of the index layer, and A_i(i=1,2,3,4,5,6) refers to the weight set of the index layer under the criteria layer. Calculate the primary comprehensive evaluation based on the index layer's index weight set A_i(i=1,2,3,4,5,6) and the judgment matrix R_i(i=1,2,3,4,5,6). B_i represents: $B_i = A_i \ o \ R_i$(i=1,2,3,4,5,6).

The primary comprehensive evaluation result concluded from the above method is as follows.

$B_1=A_1 \circ R_1$=(0.56841，0.34253，0.08906，0)；

$B_2=A_2 \circ R_2$=(0.71967，0.24807，0.03216，0)；

$B_3=A_3 \circ R_3$=(0.82296，0.13945，0.03779，0)；

$B_4=A_4 \circ R_4$=(0.96894，0.03106，0，0)；

$B_5=A_5 \circ R_5$=(0.75722，0.22859，0.01429，0)；

$B_6=A_6 \circ R_6$=(0.77151，0.17144，0.05715，0)

The above determination vector is regarded as the fuzzy judgment matrix R of layer B, calculate the secondary comprehensive determination vector, and

$R=[B_1, B_2, B_3, B_4, B_5, B_6]^T$,

$B=A \circ R=A \circ [B_1, B_2, B_3, B_4, B_5, B_6]^T$=(0.81326，0.15699，0.02958，0)

The result showed that 81.326% of the experts believe that the implementation level of the Beijiang Electric Power Plant circular economy is excellent, 15.699% believe good, 2.958% believe fair and nobody believe poor.

5.3.2.4 Evaluation Results Analysis

Because of the maximum membership principle described in Chapter 3.7.1, an indicator α was used to judge the validity of the maximum membership principle, which can explain the relative confidence level of the implementing maximal membership principle. (Zhu *et al.*, 2016)

The relative degree of confidence in the principle of membership,

①when $\alpha = +\infty$, maximum membership principle is complete validity.

②when $1 \leq \alpha < +\infty$, maximum membership principle is comparative validity.

③when $0.5 \leq \alpha < 1$, maximum membership principle is general validity.

④when $0 < \alpha < 0.5$, maximum membership principle is less validity.

⑤when $\alpha = 0$, maximum membership principle is invalidity.

According to the maximum membership principle in fuzzy mathematics, 0.81326 is the peak value of the determination vector, and the corresponding evaluation is “excellent”, which compared to other judgment values possesses absolute advantage. An index for judging the validity of the maximum membership principle:

$$\alpha = \frac{n\beta - 1}{2\gamma(n-1)} = 2.39199$$

Where, $n = 4, \beta = 0.81326,$ and $\gamma = 0.15699$. Due to $1 \leq \alpha < +\infty$, maximum membership principle is comparative validity.

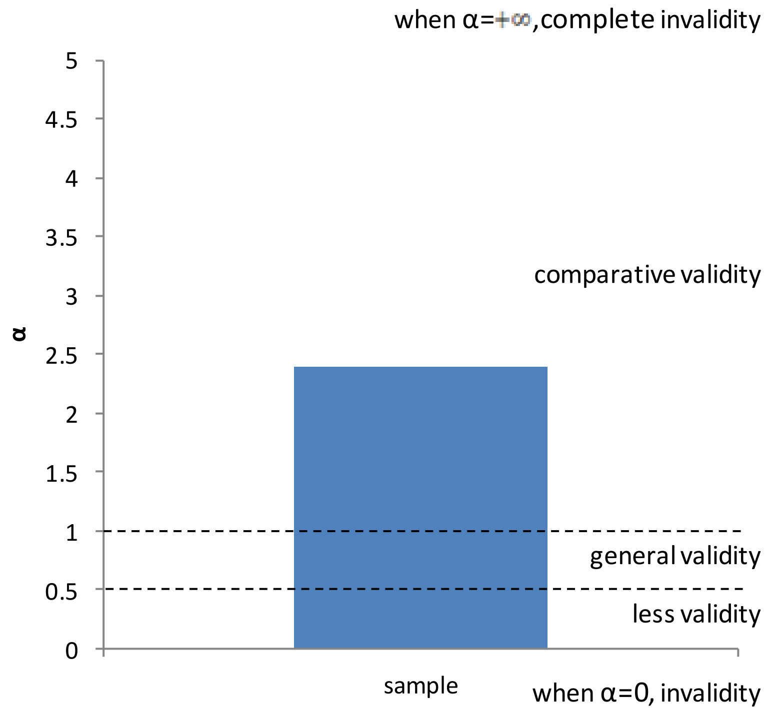

Figure 5.2 The relationship between indicator α and the maximum membership principle validity

Therefore, it is determined that, in terms of the implementation level of the Beijiang Electric Power Plant circular economy, the fuzzy comprehensive evaluation result is “excellent” when all factor and indexes on every layer are considered, which is consistent with the enterprise fact.

5.4 Summary

This thesis, based on a comprehensive analysis of domestic industries and enterprises implementing the circular economic development model, studies the power enterprise circular economic development level evaluation index system and the evaluation methods, and come to the following conclusions:

(1) After looking up extensive literature related to enterprise circular economy evaluation, the author, from the aspects of economic benefits, resource & energy consumption, waste discharge, recycle & reuse, environmental protection construction & technological innovation capabilities, and enterprise management & social benefits, establishes a set of index system applicable to the implemented effect of power enterprise circular economy, adopts the AHP method to determine the index weight value, and builds a complete enterprise circular economy evaluation index system.

(2) Taking the Beijiang Electric Power Plant as an example, the author introduces the characteristics of circular economic development, in combination with the power sector circular economy evaluation index system, adopts the fuzzy comprehensive evaluation method to evaluate the development level of circular economy, and also illustrates the application of the index system, which finally having the effects of guiding the implementation of enterprise circular economy, completing the circular economy theory, and expanding enterprise evaluation directions and fields.

6. Conclusion and discussion

6.1 Summary of conclusion & discussion of each chapter

(1) Chapter 1

This chapter introduces the development of China’s circular economy and renewable, and the significance of this research.

(2) Chapter 2

This chapter introduces relevant studies and research objectives of circular economy evaluation system, and summarizes the theoretical basis and process method of using AHP to determine the weight value of the index system and introduces the evaluation steps and application methods of the fuzzy comprehensive evaluation method.

(3) Chapter 3

This chapter introduces the principles and methods for establishing a circular economy index system and the steps and methods for using the AHP method to screen indexes. By using this method, the alternative index of the circular economy evaluation system of eco-industrial parks and enterprises are respectively screened, and the indexes of the two evaluation systems are respectively determined.

The eco-industrial park comprehensive evaluation index system is divided into four levels: taking the coordinated development degree of the park system and the comprehensive development level as the general objective of the eco-industrial park evaluation; According to the type characteristics of the integrated eco-industrial park, the index system is divided into economic development, Resource utilization, environmental protection, ecological civilization, park management and social progress. Each of the first-level indicators is divided into two second-level indicators of rigid index and flexible index. The rigid indexes include economic strength, resource consumption, Strength, ecological construction, management level, employment status and happiness index, reflecting the status of the eco-industrial park development and construction results; flexible indicators include economic development potential, recycling, pollution control, ecological improvement potential and infrastructure support Capacity 5, reflecting the stability of the eco-industrial park development, sustainability and coordination.

The evaluation index system of circular economy of enterprises sets a universal index system suitable for evaluating the implementation of circular economy of enterprises from the aspects of economic benefits, resource and energy utilization, waste discharge, recycling, business management and social benefits. And the meaning of each evaluation index and calculation method is described.

(4) Chapter 4

The multi-level extension comprehensive evaluation method is used to build an eco-industrial park's evaluation system of coordinated development degree and comprehensive development level. The model is used to evaluate and analyze the TEDA eco-industrial park. The evaluation results show that economic development, resource utilization, environment the coordinated development of protection, ecological civilization, park management and social progress is weak and belongs to the weak coordination. Its development level is relatively low compared with the advanced parks in the same type and developed countries in the country and belongs to the weak cycle. TEDA into the stable and sustainable development of circular economy still need hard work, and the impact of the evaluation results were analyzed and put forward improved strategies and measures.

(5) Chapter 5

The four typical industries of power electric, steel, coal and papermaking are selected respectively, and the development process of circular economy is introduced respectively. According to the characteristics of the industry, the characteristics of circular economy are analyzed. Based on the universal index system and the characteristics of different industries, corresponding characteristic indexes were considered, and the characteristic index system suitable for different specific industries was described. And the weight values respectively were analyzed by analytic hierarchy process.

Taking Tianjin SDIC Tianjin Beijiang Power Plant as a case, this paper introduces the characteristics of its circular economy development. Combined with the evaluation index system of circular economy in the power industry, this paper evaluates the level of its circular economy by using the fuzzy comprehensive evaluation method and applies the index system be explained.

6.2 Clarified findings from this thesis totally

(1) The circular economy index systems were improved. Circular economy is generally divided into three research levels: cities, industrial parks and enterprises. Because the existing studies mainly focus on cities level, this study mainly focuses on industrial parks and enterprises. Through index screening, industrial park circular economy index system and enterprise circular economy index system were established. Industrial Park circular economy index system contains 6 criterion layers and 50 evaluation indexes. Enterprise circular economy index system contains 6 criterion layers and 34 evaluation indexes. In addition, due to the different performance of the evaluation indexes in different industries, the characteristic indexes have been added to the already established enterprise evaluation system. Four typical industries have been specifically analyzed: power, steel, coal and papermaking.

(2) The weights of each evaluation index in the circular economy index system were analyzed and determined. The meaning of each index in the established evaluation index system was explained and the weight was determined through questionnaire and expert consultation analysis.

In the industrial park level, the weight of economic development is 0.3994, the weight of resource utilization is 0.1998, the weight of environmental protection is 0.1998, the weight of ecological civilization is 0.1045, the weight of park administration is 0.0604, and the weight of social progress is 0.0361. Economic development has the greatest impact on the eco-industrial park coordinated development degree & comprehensive development level, followed by resource utilization and environmental protection, and then ecological civilization, park administration, and social progress in turn.

In the enterprise level, the weight of Economic Benefits is 0.1173, the weight of Resource & Energy Consumption is 0.2031, the weight of Waste Discharge is 0.2031, the weight of Recycle & Reuse is 0.3383, the weight of Environmental Protection

Construction & Technological Innovation Capabilities is 0.0690, and the weight of Enterprise Management & Social Benefits is 0.0690. Recycle & Reuse has the greatest impact on the enterprise coordinated development degree & comprehensive development level, followed by Resource & Energy Consumption and the weight of Waste Discharge, and then Environmental Protection Construction & Technological Innovation Capabilities and the weight of Enterprise Management & Social Benefits.

(3) Multi-level extension comprehensive evaluation method is applied to build the model of coordinated development degree and integrated development level of the SIEIPs, and use this model to evaluate TEDA Eco-Industrial Park. The results show that the coordinated development degree of TEDA EIPs is weak, belong to weakly coordinated, the comprehensive development level is not high, belong to weak circulation. Therefore TEDA will have to make more effort to go into the stable and sustainable development of circular economy status. In addition, the evaluation results are factor analyzed, proposing strategies and measures to improve.

Taking the Tianjin SDIC power plant as an enterprise example, its characteristic cycle of economic development was introduced. Combined with the evaluation index system of power industry circular economy, the level of economic development cycle was evaluated using a fuzzy comprehensive evaluation method, and the application of the index system was described.

6.3 Countermeasures to be taken for improvement of Eco-Industrial Parks and Enterprises

(1) Increase funding for scientific research and increase scientific and technological innovation and R&D of science and technology. On the one hand, the establishment of enterprise personnel introduction, nurturing system and high-tech talent management system for enterprises to create an appropriate environment for independent innovation; the other hand, increase scientific and technological research and development and technology patent applications incentives to speed up the cultivation of a group with independent knowledge Property rights of original technology, increase the protection of intellectual property rights, improve the intellectual property protection system.

(2) Reduce the integrated energy consumption per unit of industrial added value and improve the comprehensive utilization rate of industrial solid waste. On the one hand, the key energy-using enterprises in the park to carry out energy-saving management, enterprise energy management performance evaluation, development of corporate energy efficiency target responsibility system, regularly conduct energy-saving target assessment, and promote the use of energy-saving equipment and transformation of technological advances to speed up industrial energy monitoring Management and other basic capabilities, and actively develop low-carbon skills and low-carbon industries; the other hand, the relevant state departments to speed up the preparation and release of industrial energy efficiency guidelines, put forward energy efficiency indicators of major industries. In addition, the promotion of advanced and applicable technologies and fostering of a batch of large-scale industrial solid waste comprehensive utilization specialized enterprises with high technical equipment level and market competitiveness.

(3) Reduce the amount of wastewater generated per 10,000 yuan of industrial added value and COD production per 10,000 yuan of industrial added value. Mainly from the following three aspects: First, increase the use of cleaner production technology

and implementation efforts, from the source to reduce; second is the use of new technology, new methods of pollution control from the sewage treatment process to improve; third is the introduction of advanced sewage treatment equipment and Technology, increase the end of governance.

(4) Improve air quality and increase the ratio of environmental investment in GDP. On the one hand, clean energy and renewable energy sources should be used to limit the emission of particulate pollutants. A vehicle restriction system should be adopted to encourage people to take public transport, take short trips or walk on foot. On the other hand, supervision of sewage-type enterprises should be strengthened to ensure that Its environmental input, set admission restrictions on enterprises, increase environmental protection enterprises to enter.

(5) Increase the ratio of professionals in environmental management agencies. On the one hand, we should strengthen professional training and education for staff of existing environmental management agencies. On the other hand, we should increase the recruitment of professionals with highly educated environmental professionals through job fairs in universities.

(6) Increase the employment rate of circular economy. On the one hand, it can increase employment by increasing the number of eco-industrial chains; on the other hand, it can increase employment by developing environmental industries and opening up new areas of production

6.4 Future tasks for further progress of this theme

(1) Further study of comprehensive evaluation method. Since the main research object of this paper is the establishment of the evaluation index system, we do not conduct any further research on the subsequent comprehensive evaluation methods, but introduce and select the more common and easy-to-understand fuzzy comprehensive evaluation method, and define the fuzzy operator as the weighted average fuzzy Operator, this method is more general and easy to calculate, but its accuracy and wide applicability have yet to be studied. In the future study can be studied to take other mathematical models and comprehensive evaluation methods, the evaluation results are more true and accurate.

(2) Due to the limitation of time and the difficulty of acquiring some index data, this paper only evaluates TEDA Eco-Industrial Park, does not choose the same type of park for horizontal comparison, but also because TEDA Eco-Industrial Park can be open statistics, so only selected in 2010 for evaluation research, do not have vertical comparability.

(3) Research on the Evaluation Index System of Circular Economy in Other Industries. This article selects the steel, coal, electricity and papermaking four major industries, these industries have the characteristics of high energy and material consumption, pollutant emissions and so on. However, the analysis of other industry characteristic indexes and the construction of the evaluation index system have yet to be further carried out. Such as the use of waste rubber, electroplating and other industries, as well as other industries that have implemented or are in need of implementing circular economy, further analyze the characteristics of their implementation of circular economy, and establish more indicators for evaluating the circular economy of their respective industries.

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APPENDIX

Appendix 1 Expert Consultation Questionnaire of Industrial Park Circular Economy Evaluation Primary Index System

Dear expert:

Hello, this questionnaire's purpose is to screen the initial indexes, remove repetitive unnecessary indexes.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

1. The elementary index system contains 12 state layers C1~C12. Each state layer contains several indexes. The indexes contained in each state layer need to be filtered.
2. Scoring methods: The relationships between indexes are independent, equal and overlap and contain and contained relationship:

Independent relationship is 0,
Equal relationship is 1,
Content or information overlap relationship is 2,
Included or included relationship is 3.

Date:
Position/Title:
Employer:

1. Screening of "economic strength" indexes

Economic Strength C1	Industrial output value M11,Industrial Added Value M12,Per-capital GDP M13,Per-capital Industrial Added Value M14,GDP Average Annual Growth Rate M15,Percentage of the Added Value of Tertiary Industry in GDP M16,Economic Output Density M17,Input-output ratioM18,Rate of Resources Output M19,Rate of Energy Output M110,Rate of Water Resources Output M111

	M11	M12	M13	M14	M15	M16	M17	M18	M19	M110	M111
M11	1										
M12		1									
M13			1								
M14				1							
M15					1						
M16						1					
M17							1				
M18								1			
M19									1		
M110										1	
M111											1

2. Index Screening of "Economic Development Potential"

Economic Development Potentials C2	Percentage of Scientific Research Input in GDP M21, Contribution Rate of Technological Progress to Industrial Output ValueM22, Percentage of High-tech Industry Output in Total Industrial Output Value M23, Advanced Technology Share M24, Product Category M25, Substitutability of Raw Materials Source M26, Waste Chain Completeness M27, Eco-industrial Chain Run Flexible M28, Enterprises Correlation M29, Mature Eco-industrial Chain Condition M210

	M21	M22	M23	M24	M25	M26	M27	M28	M29	M210
M21	1									
M22		1								
M23			1							
M24				1						
M25					1					
M26						1				
M27							1			
M28								1		
M29									1	
M210										1

3. Index Screening of "resource consumption"

Resource Consumption C3	Comprehensive Energy Consumption per Unit of Industrial Added Value M31, Comprehensive Energy Consumption Elasticity Coefficient M32, Fresh Water Consumption per Unit of Industrial Added Value M33, Fresh Water Consumption Elasticity Coefficient M34, Material Loss RateM35, Comprehensive Energy Consumption Elasticity Coefficient M36, Fresh Water Consumption Elasticity Coefficient M37

	M31	M32	M33	M34	M35	M36	M37
M31	1						
M32		1					
M33			1				
M34				1			
M35					1		
M36						1	
M37							1

4. Index Screening of “Recycling”

Recycling Degree C4	Energy Cascade UtilizationM41, Repetitiveness of Industrial Water M42, Comprehensive Utilization Ratio of Industrial Solid Wastes M43, Industrial Exhaust Recycling RateM44, Industrial Waste Heat Utilization rateM45, Industrial Pressure Recovery RateM46

	M41	M42	M43	M44	M45	M46	M47
M41	1						
M42		1					
M43			1				
M44				1			
M45					1		
M46						1	
M47							1

5. Index Screening of “Emission intensity”

Sewage Discharge Intensity C5	Wastewater Production per Unit Product M51, Wastewater Production per Unit of Industrial Added Value M52, Solid Waste Production per Unit Product M53, Solid Waste Production per Unit of Industrial Added Value M54, COD Production per Unit of Industrial Added Value M55, SO_2 Emission per Unit of Industrial Added Value M56, Exhaust Discharge per Unit of Industrial Added Value M57, Smoke and Dust Discharge per Unit of Industrial Added Value M58,COD Emission Elasticity Coefficient M59,SO_2 Emission Elasticity Coefficient M510

	M51	M52	M53	M54	M55	M56	M57	M58	M59	M510
M51	1									
M52		1								
M53			1							
M54				1						
M55					1					
M56						1				
M57							1			
M58								1		
M59									1	
M510										1

6. Index Screening of "Pollution control"

Pollution Control C6	Rate of Industrial Wastewater Discharge Compliance M61, Rate of Industrial Wastewater Discharge Reduction M62, Rate of Industrial Exhaust Discharge Compliance M63, Rate of Industrial Exhaust Discharge Reduction M64, Rate of Industrial Solid Wastes Discharge Reduction M65, Rate of Household Wastes Hazard-free Treatment M66, Rate of Hazardous Wastes Treatment and Disposal M67, Rate of Main Air Pollutants Emission Compliance M68, Rate of Sewage Treatment Plant Effluent Quality Compliance M69, Average Regional Environmental Noise M610, Average Road Traffic Noise M611

	M61	M62	M63	M64	M65	M66	M67	M68	M69	M610	M611
M61	1										
M62		1									
M63			1								
M64				1							
M65					1						
M66						1					
M67							1				
M68								1			
M69									1		
M610										1	
M611											1

7. Index Screening of "Ecological construction"

Ecological Construction C7	Coverage Rate of Regulated Area of Dust and Smoke M71, Compliance Rate of Park Surface Water Environmental Quality M72, Compliance Rate of Park Groundwater Environmental Quality M73, Rate of Secondary Air Quality Standard Compliance M74, Rate of Park Greenery Coverage M75, Per-capita Public Green Area M76, Average Air Quality Rating M77, Average Water Environment Quality Level M78, Satisfaction of the Public toward the Environment M79

	M71	M72	M73	M74	M75	M76	M77	M78	M79
M71	1								
M72		1							
M73			1						
M74				1					
M75					1				
M76						1			
M77							1		
M78								1	
M79									1

8. Index Screening of "Ecological Improvement Potential"

Ecological Improvement Potentials C8	Percentage of Environmental Protection in GDP M81, Percentage of Clean Energy in Total Energy M82, Environmentally Friendliness of ProductsM83, Ratio of Public Transport Sharing M84

	M81	M82	M83	M84
M81	1			
M82		1		
M83			1	
M84				1

9. Index Screening of "Management level"

Management Level C9	Establishment and Implementation of Environmental Management System M91, Park Environmental Report Preparation M92, Enterprise Cleaner Production Audit Implementation RateM93, Large-scale Enterprises 15014000 Certification RateM94, "Three simultaneous" Pass Rate M95, Completeness of Environmental Management System M96, Monitoring on Park Change M97, Eco-industrial Training M98

	M91	M92	M93	M94	M95	M96	M97	M98
M91	1							
M92		1						
M93			1					
M94				1				
M95					1			
M96						1		
M97							1	
M98								1

10. Index Screening of “Infrastructure support capacity”

Infrastructure Supporting Capacity C10	Water Supply and Drainage Network Coverage Rate M101, Central Heating RateM102, Completeness of Supporting Infrastructures M103, Completeness of Information System M104, Completeness of Waste Collection System M105, Completeness of Waste Centralized Treatment Facilities M106, Percentage of Professionals in Environmental Administration Organizations M107

	M101	M102	M103	M104	M105	M106	M107
M101	1						
M102		1					
M103			1				
M104				1			
M105					1		
M106						1	
M107							1

11. Index Screening of “employment status”

Employment C11	Ratio of the Number of Tertiary Industry Employees M111, Ratio of Employment Added by Developing Circular Economy M112, Re-employment RatioM113

	M111	M112	M113
M111	1		
M112		1	
M113			1

12. Index Screening of “Happiness index”

Happiness Index C12	Engel Coefficient M121, Social Security Coverage M122, Percentage of Culture-Education-Health Added Value in GDP M123

	M121	M122	M123
M121	1		
M122		1	
M123			1

Appendix 2 Expert Consultation Questionnaire of Enterprise Circular Economy Evaluation Primary Index System

Dear expert:

Hello, this questionnaire's purpose is to screen the initial indexes, remove repetitive unnecessary indexes.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

3. The elementary index system contains 6 state layers C1~C6. Each state layer contains several indexes. The indexes contained in each state layer need to be filtered.
4. Scoring methods: The relationships between indexes are independent, equal and overlap and contain and contained relationship:

Independent relationship is 0,

Equal relationship is 1,

Content or information overlap relationship is 2,

Included or included relationship is 3.

Date:
Position/Title:
Employer:

1. Screening of "Economic Benefits" indexes

Economic Benefits C_1	Growth Rate of Sales RevenueM_{11}, Net Return on AssetsM_{12}, Return Rate on SalesM_{13}, Economic Output DensityM_{14}, Input-output RatioM_{15}, Growth Rate of Industrial Added ValueM_{16}, Economic Benefits from the Implementation of Circular EconomyM_{17}, Return Rate on Total AssetsM_{18}, Non-power Output Value RatioM_{19}

	M11	M12	M13	M14	M15	M16	M17	M18	M19
M11	1								
M12		1							
M13			1						
M14				1					
M15					1				
M16						1			
M17							1		
M18								1	
M19									1

2. Index Screening of " Resource & Energy Consumption "

Resource & Energy Consumption C_2	Standard Unit Coal Consumption for Power GenerationM_{21}, Standard Unit Coal Consumption for Power SupplyM_{22}, Water Consumption for Unit ProductM_{23}, Energy Use Reduction RateM_{24}, Raw-materials Use Reduction RateM_{25}, Comprehensive Station Service Power Consumption RateM_{26}, Oil Consumption for Unit ProductM_{27}, Energy Utilization EfficiencyM_{28}, Annual Heat-to-electric RatioM_{29}

	M21	M22	M23	M24	M25	M26	M27	M28	M29
M21	1								
M22		1							
M23			1						
M24				1					
M25					1				
M26						1			
M27							1		
M28								1	
M29									1

3. Index Screening of " Waste Discharge "

Waste Discharge C_3	Standard Discharge Rate of WastewaterM_{31}、Standard Discharge Rate of Exhaust GasM_{32}、Safe Disposal Rate of Hazardous WastesM_{33}、Rate of Environmental Noise Reaching StandardsM_{34}、Flue Dust Emission for Unit ProductM_{35}, Sulfur Dioxide Emission for Unit ProductM_{36}, Nitric Oxide Emission for Unit ProductM_{37}, Ash Residue Production for Unit ProductM_{38}, Wastewater Production for Unit ProductM_{39}

	M31	M32	M33	M34	M35	M36	M37	M38	M39
M31	1								
M32		1							
M33			1						
M34				1					
M35					1				
M36						1			
M37							1		
M38								1	
M39									1

4. Index Screening of "Recycle & Reuse"

Recycle & Reuse C_4	Comprehensive Repeated Utilization Factor of Domestic SewageM_{41}, Comprehensive Repeated Utilization Factor of Industrial WastewaterM_{42}, Reuse Water Utilization RatioM_{43}, Comprehensive Utilization Factor of desulfurization gypsumM_{44}, Comprehensive Utilization Factor of Coal AshM_{45}, Comprehensive Utilization Factor of Bottom AshM_{46}, Comprehensive Utilization Factor of Exhaust HeatM_{47}

	M41	M42	M43	M44	M45	M46	M47
M41	1						
M42		1					
M43			1				
M44				1			
M45					1		
M46						1	
M47							1

5. Index Screening of "Environmental Protection Construction & Technological Innovation Capabilities"

Environmental Protection Construction & Technological Innovation Capabilities C_5	Rate of Enterprise Environmental Protection InvestmentM_{51}, Environmental Protection Equipment ProportionM_{52}, Enterprise Eco-environmental Transformation PotentialsM_{53}, Innovation Input CapabilityM_{54}, Green-technology Implementation LevelM_{55}, Technological R&D CapabilityM_{56}, Ratio of Scientific and Technical PersonnelM_{57}

	M51	M52	M53	M54	M55	M56	M57
M51	1						
M52		1					
M53			1				
M54				1			
M55					1		
M56						1	
M57							1

6. Index Screening of “Enterprise Management & Social Benefits”

Enterprise Management & Social Benefits C_6	Enterprise Circular Economy Knowledge TrainingM_{61}, Enterprise Circular Economy Norms ConstructionM_{62}, Enterprise Information System ConstructionM_{63}, Management Awareness about Environmental ProtectionM_{64}, Employee Awareness about Environmental ProtectionM_{65}, Enterprise Brand Value and Social ImageM_{66}

	M61	M62	M63	M64	M65	M66
M61	1					
M62		1				
M63			1			
M64				1		
M65					1	
M66						1

Appendix 3 Expert Consultation Questionnaire for Determining Index Weight of Eco-Industrial Parks Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

5. The elementary index system contains 6 criterion layer B1~B6, 12 state layers C1~C12 and 50 Variable Layer M1~M50. (shown in Table1)
6. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Elementary Evaluation Index System of Eco-Industrial Parks Circular Economy

Criterion Layer B	State Layer C	Variable Layer M
Economic Development B1	Economic Strength, C1	Per-capital Industrial Added Value (ten thousand yuan/capital) M1↑
		GDP Average Annual Growth Rate (%) M2↑
		Percentage of the Added Value of Tertiary Industry in GDP (%) M3↑
		Economic Output Density (100 Million yuan/sq.km.) M4↑
		Rate of Energy Output (10 Thousand yuan/tce) M5↑
		Rate of Water Resources Output (10 Thousand yuan/m^3) M6↑
	Economic Development Potentials C2	Percentage of Scientific Research Input in GDP (%)M7↑
		Percentage of High-tech Industry Output in Total Industrial Output Value (%) M8↑
		Enterprises Correlation M9↑
		Waste Chain Completeness M10↑
		Substitutability of Raw Materials Source M11↑
Resource Utilization B2	Resource Consumption C3	Comprehensive Energy Consumption per Unit of Industrial Added Value (tce/10 Thousand yuan)M12↓
		Fresh Water Consumption per Unit of Industrial Added Value (m^3/10 Thousand yuan) M13↓
		Comprehensive Energy Consumption Elasticity Coefficient M14↓
		Fresh Water Consumption Elasticity Coefficient M15↓
	Recycling Degree C4	Repetitiveness of Industrial Water (%) M16↑
		Comprehensive Utilization Ratio of Industrial Solid Wastes (%) M17↑
Environmental Protection B3	Sewage Discharge Intensity C5	Wastewater Production per Unit of Industrial Added Value (t/10 Thousand yuan) M18↓
		Solid Waste Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M19↓
		COD Production per Unit of Industrial Added Value (kg/10 Thousand yuan) M20↓
		SO_2 Emission per Unit of Industrial Added Value (kg/10 Thousand yuan) M21↓
		COD Emission Elasticity Coefficient M22↓
		SO_2 Emission Elasticity Coefficient M23↓

(Continued)

Criterion Layer B	State Layer C	Variable Layer C
Environmental Protection B3	Pollution Control C6	Rate of Industrial Wastewater Discharge Compliance (%) M24↑
		Rate of Industrial Wastewater Discharge Reduction (%) M25↑
		Rate of Main Air Pollutants Emission Compliance (%)M26↑
		Rate of Industrial Solid Wastes Discharge Reduction (%) M27↑
		Rate of Household Wastes Hazard-free Treatment (%) M28↑
		Rate of Hazardous Wastes Treatment and Disposal (%)M29↑
		Rate of Sewage Treatment Plant Effluent Quality Compliance (%) M30↑
		Average Regional Environmental Noise (db) M31↓
		Average Road Traffic Noise (db) M32↓
Eco-friendly B4	Ecological Construction C7	Coverage Rate of Regulated Area of Dust and Smoke (%) M33↑
		Rate of Secondary Air Quality Standard Compliance (%) M34↑
		Rate of Park Greenery Coverage(%) M35↑
		Satisfaction of the Public toward the Environment (%) M36↑
	Ecological Improvement Potentials C8	Percentage of Environmental Protection in GDP (%) M37↑
		Percentage of Clean Energy in Total Energy (%) M38↑
		Ratio of Public Transport Sharing (%) M39↑
Park Administration B5	Management Level C9	Park Environmental Report Preparation M40↑
		Completeness of Environmental Management System M41↑
		Monitoring on Park Change M42↑
		Eco-industrial Training M43↑
	Infrastructure Supporting Capacity C10	Completeness of Supporting InfrastructuresM44↑
		Completeness of Information System M45↑
		Percentage of Professionals in Environmental Administration Organizations (%) M46↑
Social Progress B6	Employment C11	Ratio of the Number of Tertiary Industry Employees (%) M47↑
		Ratio of Employment Added by Developing Circular Economy (%) M48↑
	Happiness Index C12	Engel Coefficient (%) M49↓
		Social Security Coverage (%) M50↑

(1) Criterion Layer B

B1	Economic Development	9	8	7	6	5	4	3	2	1	0
B2	Resource Utilization	9	8	7	6	5	4	3	2	1	0
B3	Environmental Protection	9	8	7	6	5	4	3	2	1	0
B4	Eco-friendly	9	8	7	6	5	4	3	2	1	0
B5	Park Administration	9	8	7	6	5	4	3	2	1	0
B6	Social Progress	9	8	7	6	5	4	3	2	1	0

(2) State Layer C

C1	Economic Strength	9	8	7	6	5	4	3	2	1	0
C2	Economic Development Potentials	9	8	7	6	5	4	3	2	1	0
C3	Resource Consumption	9	8	7	6	5	4	3	2	1	0
C4	Recycling Degree	9	8	7	6	5	4	3	2	1	0
C5	Sewage Discharge Intensity	9	8	7	6	5	4	3	2	1	0
C6	Pollution Control	9	8	7	6	5	4	3	2	1	0
C7	Ecological Construction	9	8	7	6	5	4	3	2	1	0
C8	Ecological Improvement Potentials	9	8	7	6	5	4	3	2	1	0
C9	Management Level	9	8	7	6	5	4	3	2	1	0
C10	Infrastructure Supporting Capacity	9	8	7	6	5	4	3	2	1	0
C11	Employment	9	8	7	6	5	4	3	2	1	0
C12	Happiness Index	9	8	7	6	5	4	3	2	1	0

(3) Economic Strength C1

M1	Per-capital Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M2	GDP Average Annual Growth Rate	9	8	7	6	5	4	3	2	1	0
M3	Percentage of the Added Value of Tertiary Industry in GDP	9	8	7	6	5	4	3	2	1	0
M4	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M5	Rate of Energy Output	9	8	7	6	5	4	3	2	1	0
M6	Rate of Water Resources Output	9	8	7	6	5	4	3	2	1	0

(4) Economic Development Potentials C2

M7	Percentage of Scientific Research Input in GDP	9	8	7	6	5	4	3	2	1	0
M8	Percentage of High-tech Industry Output in Total Industrial Output Value	9	8	7	6	5	4	3	2	1	0
M9	Enterprises Correlation	9	8	7	6	5	4	3	2	1	0
M10	Waste Chain Completeness	9	8	7	6	5	4	3	2	1	0
M11	Substitutability of Raw Materials Source	9	8	7	6	5	4	3	2	1	0

(5) Resource Consumption C3

M12	Comprehensive Energy Consumption per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M13	Fresh Water Consumption per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M14	Comprehensive Energy Consumption Elasticity Coefficient	9	8	7	6	5	4	3	2	1	0
M15	Fresh Water Consumption Elasticity Coefficient	9	8	7	6	5	4	3	2	1	0

(6) Recycling Degree C4

M16	Repetitiveness of Industrial Water	9	8	7	6	5	4	3	2	1	0
M17	Comprehensive Utilization Ratio of Industrial Solid Wastes	9	8	7	6	5	4	3	2	1	0

(7) Sewage Discharge Intensity C5

M18	Wastewater Production per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M19	Solid Waste Production per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M20	COD Production per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0
M21	SO_2 Emission per Unit of Industrial Added Value	9	8	7	6	5	4	3	2	1	0

M22	COD Emission Elasticity Coefficient	9	8	7	6	5	4	3	2	1	0
M23	SO_2 Emission Elasticity Coefficient	9	8	7	6	5	4	3	2	1	0

(8) Pollution Control C6

M24	Rate of Industrial Wastewater Discharge Compliance	9	8	7	6	5	4	3	2	1	0
M25	Rate of Industrial Wastewater Discharge Reduction	9	8	7	6	5	4	3	2	1	0
M26	Rate of Main Air Pollutants Emission Compliance	9	8	7	6	5	4	3	2	1	0
M27	Rate of Industrial Solid Wastes Discharge Reduction	9	8	7	6	5	4	3	2	1	0
M28	Rate of Household Wastes Hazard-free Treatment	9	8	7	6	5	4	3	2	1	0
M29	Rate of Hazardous Wastes Treatment and Disposal	9	8	7	6	5	4	3	2	1	0
M30	Rate of Sewage Treatment Plant Effluent Quality Compliance	9	8	7	6	5	4	3	2	1	0
M31	Average Regional Environmental Noise	9	8	7	6	5	4	3	2	1	0
M32	Average Road Traffic Noise	9	8	7	6	5	4	3	2	1	0

(9) Ecological Construction C7

M33	Coverage Rate of Regulated Area of Dust and Smoke	9	8	7	6	5	4	3	2	1	0
M34	Rate of Secondary Air Quality Standard Compliance	9	8	7	6	5	4	3	2	1	0
M35	Rate of Park Greenery Coverage	9	8	7	6	5	4	3	2	1	0
M36	Satisfaction of the Public toward the Environment	9	8	7	6	5	4	3	2	1	0

(10) Ecological Improvement Potentials C8

M37	Percentage of Environmental Protection in GDP	9	8	7	6	5	4	3	2	1	0
M38	Percentage of Clean Energy in Total Energy	9	8	7	6	5	4	3	2	1	0
M39	Ratio of Public Transport Sharing	9	8	7	6	5	4	3	2	1	0

(11) Management Level C9

M40	Park Environmental Report Preparation	9	8	7	6	5	4	3	2	1	0
M41	Completeness of Environmental Management System	9	8	7	6	5	4	3	2	1	0
M42	Monitoring on Park Change	9	8	7	6	5	4	3	2	1	0
M43	Eco-industrial Training	9	8	7	6	5	4	3	2	1	0

(12) Infrastructure Supporting Capacity C10

M44	Completeness of Supporting Infrastructures	9	8	7	6	5	4	3	2	1	0
M45	Completeness of Information System	9	8	7	6	5	4	3	2	1	0
M46	Percentage of Professionals in Environmental Administration Organizations	9	8	7	6	5	4	3	2	1	0

(13) Employment C11

M47	Completeness of Supporting Infrastructures	9	8	7	6	5	4	3	2	1	0
M48	Completeness of Information System	9	8	7	6	5	4	3	2	1	0

(14) Happiness Index C12

M49	Engel Coefficient	9	8	7	6	5	4	3	2	1	0
M50	Social Security Coverage	9	8	7	6	5	4	3	2	1	0

Appendix 4 Expert Consultation Questionnaire for Determining Index Weight of Enterprises Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

7. The elementary index system contains 6 state layers C1~C6 and 34 Variable Layer M1~M34. (shown in Table1)
8. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Enterprise Circular Economy Evaluation Index System

	Indexes	Unit
Economic Benefits C1	Growth Rate of Sales Revenue M1	%
	Net Return on Assets M2	%
	Economic Output Density M3	ten thousand yuan/hectare
	Economic Benefits from the Implementation of Circular Economy M4	ten thousand yuan/year
Resource & Energy Consumption C2	Raw Material Consumption Per Ten Thousand Yuan Output Value M5	t/ten thousand yuan
	Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value M6	t-standard coal/ ten thousand yuan
	Fresh Water Consumption Per Ten Thousand Yuan Output Value M7	m^3/ten thousand yuan
	Enterprise Clean Energy Utilization Rate M8	%
	Renewable Material Utilization Rate M9	%
	Energy Utilization Efficiency M10	%
	Raw Material Utilization Rate M11	%
Waste Discharge C3	Standard Discharge Rate of Wastewater M12	%
	Standard Discharge Rate of Exhaust Gas M13	%
	Safe Disposal Rate of Hazardous Wastes M14	%
	Wastewater Discharge Per Ten Thousand Yuan Output Value M15	t/ten thousand yuan
	COD Emission Per Ten Thousand Yuan Output Value M16	kg/ten thousand yuan
	Exhaust Emissions Per Ten Thousand Yuan Output Value M17	m^3/ten thousand yuan
	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value M18	m^3/ten thousand yuan
	Solid Waste Emission Per Ten Thousand Yuan Output Value M19	t/ten thousand yuan
Recycle & Reuse C4	Intermediate By-products Utilization Rate M20	%
	Wastewater Comprehensive Utilization Rate M21	%
	Solid Waste Comprehensive Utilization Rate M22	%
	Waste Heat Utilization Rate M23	%
	Packaging Material Recycling Rate M24	%
Environmental Protection Construction&Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment M25	%
	Environmental Protection Equipment Proportion M26	%
	Innovation Input Capability M27	%
	Technological R&D Capability M28	unit/hundred people
	Ratioof Scientific and Technical Personnel M29	%
Enterprise Management & Social Benefits C6	Enterprise Circular Economy Knowledge Training M30	%
	Enterprise Circular Economy Norms Construction M31	—
	Enterprise Information System Construction M32	—
	Employee Awareness about Environmental Protection M33	—
	Enterprise Brand Value and Social Image M34	—

(1) State Layer C

C1	Economic Benefits	9	8	7	6	5	4	3	2	1	0
C2	Resource & Energy Consumption	9	8	7	6	5	4	3	2	1	0
C3	Waste Discharge	9	8	7	6	5	4	3	2	1	0
C4	Recycle & Reuse	9	8	7	6	5	4	3	2	1	0
C5	Environmental Protection Construction & Technological Innovation Capabilities	9	8	7	6	5	4	3	2	1	0
C6	Enterprise Management & Social Benefits	9	8	7	6	5	4	3	2	1	0

(2) Economic Benefits C1

M1	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0
M2	Net Return on Assets	9	8	7	6	5	4	3	2	1	0
M3	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M4	Economic Benefits from the Implementation of Circular Economy	9	8	7	6	5	4	3	2	1	0

(3) Resource & Energy Consumption C2

M5	Raw Material Consumption Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M6	Comprehensive Energy Consumption Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M7	Fresh Water Consumption Per Ten Thousand	9	8	7	6	5	4	3	2	1	0

	Yuan Output Value										
M8	Enterprise Clean Energy Utilization Rate	9	8	7	6	5	4	3	2	1	0
M9	Renewable Material Utilization Rate Source	9	8	7	6	5	4	3	2	1	0
M10	Energy Utilization Efficiency	9	8	7	6	5	4	3	2	1	0
M11	Raw Material Utilization Rate	9	8	7	6	5	4	3	2	1	0

(4) Waste Discharge C3

M12	Standard Discharge Rate of Wastewater	9	8	7	6	5	4	3	2	1	0
M13	Standard Discharge Rate of Exhaust Gas	9	8	7	6	5	4	3	2	1	0
M14	Safe Disposal Rate of Hazardous Wastes	9	8	7	6	5	4	3	2	1	0
M15	Wastewater Discharge Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M16	COD Emission Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M17	Exhaust Emissions Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M18	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M19	Solid Waste Emission Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0

(5) Recycle & Reuse C4

M20	Intermediate By-products Utilization Rate	9	8	7	6	5	4	3	2	1	0
M21	Wastewater Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M22	Solid Waste Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M23	Waste Heat Utilization Rate	9	8	7	6	5	4	3	2	1	0
M24	Packaging Material Recycling Rate	9	8	7	6	5	4	3	2	1	0

(6) Environmental Protection Construction&Technological Innovation Capabilities C5

M25	Rate of Enterprise Environmental Protection Investment	9	8	7	6	5	4	3	2	1	0
M26	Environmental Protection Equipment Proportion	9	8	7	6	5	4	3	2	1	0
M27	Innovation Input Capability	9	8	7	6	5	4	3	2	1	0
M28	Technological R&D Capability	9	8	7	6	5	4	3	2	1	0
M29	Ratioof Scientific and Technical Personnel	9	8	7	6	5	4	3	2	1	0

(7) Enterprise Management & Social Benefits C6

M30	Enterprise Circular Economy Knowledge Training	9	8	7	6	5	4	3	2	1	0
M31	Enterprise Circular Economy Norms Construction	9	8	7	6	5	4	3	2	1	0
M32	Enterprise Information System Construction	9	8	7	6	5	4	3	2	1	0
M33	Employee Awareness about Environmental Protection	9	8	7	6	5	4	3	2	1	0
M34	Enterprise Brand Value and Social Image	9	8	7	6	5	4	3	2	1	0

Appendix 5 Expert Consultation Questionnaire for Determining Index Weight of Power Enterprises Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

9. The elementary index system contains 6 state layers C1~C6 and 37 variable Layers M1~M37. (shown in Table1) Due to the establishment of the evaluation index system for electric power enterprises is based on the enterprise index system, individual indices have been added or modified. Therefore, this questionnaire is only for the index level.
10. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Evaluation Index System for Circular Economy of Electric Power Enterprises

	Indexes
Economic Benefits C1	Growth Rate of Sales Revenue M1
	Net Return on Assets M2
	Economic Output Density M3
	Economic Benefits from the Implementation of Circular Economy M4
	Non-power Output Value Proportion M5
Resource & Energy Consumption C2	Standard Unit Coal Consumption for Power Generation M6
	Standard Unit Coal Consumption for Power Supply M7
	Water Consumption for Unit Product M8
	Comprehensive Station Service Power Consumption Rate M9
	Oil Consumption for Unit Product M10
	Energy Utilization Efficiency M11
	Annual Heat-to-electric Ratio M12
Waste Discharge C3	Standard Discharge Rate of Wastewater M13
	Standard Discharge Rate of Exhaust Gas M14
	Safe Disposal Rate of Hazardous Wastes M15
	Rate of Environmental Noise Reaching Standards M16
	Flue Dust Emission for Unit Product M17
	Sulfur Dioxide Emissions per unit Output Value M18
	Nitric Oxide Emission for Unit Product M19
	Ash Residue Production for Unit Product M20
	Wastewater Production for Unit Product M21
Recycle & Reuse C4	Comprehensive Repeated Utilization Factor of Domestic Sewage M22
	Comprehensive Repeated Utilization Factor of Industrial Wastewater M23
	Comprehensive Utilization Factor of desulfurization gypsum M24
	Comprehensive Utilization Factor of Coal Ash M25
	Comprehensive Utilization Factor of Bottom Ash M26
	Comprehensive Utilization Factor of Exhaust Heat M27
Environmental Protection Construction &Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment M28
	Environmental Protection Equipment Proportion M29
	Innovation Input Capability M30
	Technological R&D Capability M31
	Ratio of Scientific and Technical Personnel M32
Enterprise Management & Social Benefits C6	Enterprise Circular Economy Knowledge Training M33
	Enterprise Circular Economy Norms Construction M34
	Enterprise Information System Construction M35
	Employee Awareness about Environmental Protection M36
	Enterprise Brand Value and Social Image M37

(1) Economic Benefits C1

M1	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0
M2	Net Return on Assets	9	8	7	6	5	4	3	2	1	0
M3	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M4	Economic Benefits from the Implementation of Circular Economy	9	8	7	6	5	4	3	2	1	0
M5	Non-power Output Value Proportion	9	8	7	6	5	4	3	2	1	0

(2) Resource & Energy Consumption C2

M6	Standard Unit Coal Consumption for Power Generation	9	8	7	6	5	4	3	2	1	0
M7	Standard Unit Coal Consumption for Power Supply	9	8	7	6	5	4	3	2	1	0
M8	Water Consumption for Unit Product	9	8	7	6	5	4	3	2	1	0
M9	Comprehensive Station Service Power Consumption Rate	9	8	7	6	5	4	3	2	1	0
M10	Oil Consumption for Unit Product	9	8	7	6	5	4	3	2	1	0
M11	Energy Utilization Efficiency	9	8	7	6	5	4	3	2	1	0
M12	Annual Heat-to-electric Ratio	9	8	7	6	5	4	3	2	1	0

(3) Waste Discharge C3

M13	Standard Discharge Rate of Wastewater	9	8	7	6	5	4	3	2	1	0
M14	Standard Discharge Rate of Exhaust Gas	9	8	7	6	5	4	3	2	1	0
M15	Safe Disposal Rate	9	8	7	6	5	4	3	2	1	0

	of Hazardous Wastes										
M16	Rate of Environmental Noise Reaching Standards	9	8	7	6	5	4	3	2	1	0
M17	Flue Dust Emission for Unit Product	9	8	7	6	5	4	3	2	1	0
M18	Sulfur Dioxide Emissions per unit Output Value	9	8	7	6	5	4	3	2	1	0
M19	Nitric Oxide Emission for Unit Product	9	8	7	6	5	4	3	2	1	0
M20	Ash Residue Production for Unit Product	9	8	7	6	5	4	3	2	1	0
M21	Wastewater Production for Unit Product	9	8	7	6	5	4	3	2	1	0

(4) Recycle & Reuse C4

M22	Comprehensive Repeated Utilization Factor of Domestic Sewage	9	8	7	6	5	4	3	2	1	0
M23	Comprehensive Repeated Utilization Factor of Industrial Wastewater	9	8	7	6	5	4	3	2	1	0
M24	Comprehensive Utilization Factor of desulfurization gypsum	9	8	7	6	5	4	3	2	1	0
M25	Comprehensive Utilization Factor of Coal Ash	9	8	7	6	5	4	3	2	1	0
M26	Comprehensive Utilization Factor of Bottom Ash	9	8	7	6	5	4	3	2	1	0
M27	Comprehensive	9	8	7	6	5	4	3	2	1	0

	Utilization Factor of Exhaust Heat										

(5) Environmental Protection Construction&Technological Innovation Capabilities C5

M28	Rate of Enterprise Environmental Protection Investment	9	8	7	6	5	4	3	2	1	0
M29	Environmental Protection Equipment Proportion	9	8	7	6	5	4	3	2	1	0
M30	Innovation Input Capability	9	8	7	6	5	4	3	2	1	0
M31	Technological R&D Capability	9	8	7	6	5	4	3	2	1	0
M32	Ratio of Scientific and Technical Personnel	9	8	7	6	5	4	3	2	1	0

(6) Enterprise Management & Social Benefits C6

M33	Enterprise Circular Economy Knowledge Training	9	8	7	6	5	4	3	2	1	0
M34	Enterprise Circular Economy Norms Construction	9	8	7	6	5	4	3	2	1	0
M35	Enterprise Information System Construction	9	8	7	6	5	4	3	2	1	0
M36	Employee Awareness about Environmental Protection	9	8	7	6	5	4	3	2	1	0
M37	Enterprise Brand Value and Social Image	9	8	7	6	5	4	3	2	1	0

Appendix 6 Expert Consultation Questionnaire for Determining Index Weight of Steel Enterprises Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

11. The elementary index system contains 6 state layers C1~C6 and 37 variable Layers M1~M37. (shown in Table1) Due to the establishment of the evaluation index system for steel enterprises is based on the enterprise index system, individual indices have been added or modified. Therefore, this questionnaire is only for the index level.
12. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Evaluation Index System for Circular Economy of Steel Enterprises

	Indexes	
Economic Benefits C1	Growth Rate of Sales Revenue	M1
	Net Return on Assets	M2
	Economic Output Density	M3
	Economic Benefits from the Implementation of Circular Economy	M4
Resource & Energy Consumption C2	The Consumption of Mineral Resources per Unit of Steel	M5
	Comprehensive Energy Consumption per Unit of Steel	M6
	Fresh Water Consumption per Unit of Steel	M7
	Enterprise Clean Energy Utilization Rate	M8
	Recovered Iron Recycled Material Usage Rate	M9
	Energy Utilization Efficiency	M10
	Mineral Resources Utilization Efficiency	M11
Waste Discharge C3	Standard Discharge Rate of Wastewater	M12
	Standard Discharge Rate of Exhaust Gas	M13
	Safe Disposal Rate of Hazardous Wastes	M14
	Wastewater Discharge per Unit of Steel	M15
	Volatile Phenol Emissions per Unit of Steel	M16
	Cyanide Emissions per Unit of Steel	M17
	Exhaust Emissions per Unit of Steel	M18
	Sulfur Dioxide Emissions per Unit of Steel	M19
	Nitrogen Oxide Emissions per Unit of Steel	M20
	Solid Waste Emissions per Unit of Steel	M21
	Heavy Metals and Radioactive Sludge Emissions per Unit of Steel	M22
Recycle & Reuse C4	Intermediate Byproduct Gas Recovery and Utilization Rate	M23
	Wastewater Comprehensive Utilization Rate	M24
	Comprehensive Utilization of Iron-bearing Solid Waste in the Production Process	M25
	Waste Steel Products Recovery Rate	M26
	Waste Heat Utilization Rate	M27
Environmental Protection Construction &Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment	M28
	Environmental Protection Equipment Proportion	M29
	Innovation Input Capability	M30
	Technological R&D Capability	M31
	Ratio of Scientific and Technical Personnel	M32
Enterprise Management & Social Benefits C6	Enterprise Circular Economy Knowledge Training	M33
	Enterprise Circular Economy Norms Construction	M34
	Enterprise Information System Construction	M35
	Employee Awareness about Environmental Protection	M36
	Enterprise Brand Value and Social Image	M37

(1) Economic Benefits C1

M1	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0
M2	Net Return on Assets	9	8	7	6	5	4	3	2	1	0
M3	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M4	Economic Benefits from the Implementation of Circular Economy	9	8	7	6	5	4	3	2	1	0
M5	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0

(2) Resource & Energy Consumption C2

M6	The Consumption of Mineral Resources per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M7	Comprehensive Energy Consumption per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M8	Fresh Water Consumption per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M9	Enterprise Clean Energy Utilization Rate	9	8	7	6	5	4	3	2	1	0
M10	Recovered Iron Recycled Material Usage Rate	9	8	7	6	5	4	3	2	1	0
M11	Energy Utilization Efficiency	9	8	7	6	5	4	3	2	1	0
M12	Mineral Resources Utilization Efficiency	9	8	7	6	5	4	3	2	1	0

(3) Waste Discharge C3

M13	Standard Discharge Rate of Wastewater	9	8	7	6	5	4	3	2	1	0
M14	Standard Discharge Rate of Exhaust Gas	9	8	7	6	5	4	3	2	1	0
M15	Safe Disposal Rate of Hazardous Wastes	9	8	7	6	5	4	3	2	1	0
M16	Wastewater Discharge per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M17	Volatile Phenol Emissions per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M18	Cyanide Emissions per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M19	Exhaust Emissions per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M20	Sulfur Dioxide Emissions per Unit of Steel	9	8	7	6	5	4	3	2	1	0
M21	Nitrogen Oxide Emissions per Unit of Steel	9	8	7	6	5	4	3	2	1	0

(4) Recycle & Reuse C4

M22	Intermediate Byproduct Gas Recovery and Utilization Rate	9	8	7	6	5	4	3	2	1	0
M23	Wastewater Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M24	Comprehensive Utilization of Iron-bearing Solid Waste in the Production Process	9	8	7	6	5	4	3	2	1	0
M25	Waste Steel Products Recovery Rate	9	8	7	6	5	4	3	2	1	0
M26	Waste Heat Utilization Rate	9	8	7	6	5	4	3	2	1	0
M27	Intermediate Byproduct Gas Recovery and Utilization Rate	9	8	7	6	5	4	3	2	1	0

(5) Environmental Protection Construction&Technological Innovation Capabilities C5

M28	Rate of Enterprise Environmental Protection Investment	9	8	7	6	5	4	3	2	1	0
M29	Environmental Protection Equipment Proportion	9	8	7	6	5	4	3	2	1	0
M30	Innovation Input Capability	9	8	7	6	5	4	3	2	1	0
M31	Technological R&D Capability	9	8	7	6	5	4	3	2	1	0
M32	Ratio of Scientific and Technical Personnel	9	8	7	6	5	4	3	2	1	0

(6) Enterprise Management & Social Benefits C6

M33	Enterprise Circular Economy Knowledge Training	9	8	7	6	5	4	3	2	1	0
M34	Enterprise Circular Economy Norms Construction	9	8	7	6	5	4	3	2	1	0
M35	Enterprise Information System Construction	9	8	7	6	5	4	3	2	1	0
M36	Employee Awareness about Environmental Protection	9	8	7	6	5	4	3	2	1	0
M37	Enterprise Brand Value and Social Image	9	8	7	6	5	4	3	2	1	0

Appendix 7 Expert Consultation Questionnaire for Determining Index Weight of Coal Enterprises Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

13. The elementary index system contains 6 state layers C1~C6 and 39 variable Layers M1~M39 (shown in Table1) Due to the establishment of the evaluation index system for coal enterprises is based on the enterprise index system, individual indices have been added or modified. Therefore, this questionnaire is only for the index level.
14. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Evaluation Index System for Circular Economy of Coal Enterprises

	Indexes	
Economic Benefits C1	Growth Rate of Sales Revenue	M1
	Net Return on Assets	M2
	Economic Output Density	M3
	The Ratio of Non-coal Output Value	M4
	Economic Benefits from the Implementation of Circular Economy	M5
Resource & Energy Consumption C2	Raw Material Consumption per Unit Output Value	M6
	Comprehensive Energy Consumption Per Unit Output Value	M7
	Fresh Water Consumption Per Unit Output Value	M8
	Reserve Production Ratio	M9
	Mining Recovery Rate	M10
	Washing Rate of Raw Coal	M11
Waste Discharge C3	Standard Discharge Rate of Wastewater	M12
	Standard Discharge Rate of Exhaust Gas	M13
	Safe Disposal Rate of Hazardous Wastes	M14
	Rate of Environmental Noise Reaching Standards	M15
	Wastewater Discharge Per Ten Thousand Yuan Output Value	M16
	Exhaust Emissions Per Ten Thousand Yuan Output Value	M17
	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	M18
	Flue Dust Emission for Unit Output Value	M19
	Solid Waste Emission Per Ten Thousand Yuan Output Value	M20
Recycle & Reuse C4	Solid Waste Comprehensive Utilization Rate	M21
	Comprehensive Utilization Rate of Mine Water	M22
	Coal Recycling Water Ratio	M23
	Comprehensive Utilization Rate of Coal Gangue	M24
	Comprehensive Utilization Factor of Coal Ash	M25
	Comprehensive Utilization of Coalbed Methane	M26
	Collapse Land Reclamation Rate	M27
	Associated Mineral Development and Utilization	M28
Environmental Protection Construction & Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment	M29
	Environmental Protection Equipment Proportion	M30
	Innovation Input Capability	M31
	Technological R&D Capability	M32
	Ratio of Scientific and Technical Personnel	M33
Enterprise Management & Social Benefits C6	The Number of Deaths per Unit Production	M34
	Enterprise Circular Economy Knowledge Training	M35
	Enterprise Circular Economy Norms Construction	M36
	Enterprise Information System Construction	M37
	Employee Awareness about Environmental Protection	M38
	Enterprise Brand Value and Social Image	M39

(1) Economic Benefits C1

M1	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0
M2	Net Return on Assets	9	8	7	6	5	4	3	2	1	0
M3	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M4	The Ratio of Non-coal Output Value	9	8	7	6	5	4	3	2	1	0
M5	Economic Benefits from the Implementation of Circular Economy	9	8	7	6	5	4	3	2	1	0

(2) Resource & Energy Consumption C2

M6	Raw Material Consumption per Unit Output Value	9	8	7	6	5	4	3	2	1	0
M7	Comprehensive Energy Consumption Per Unit Output Value	9	8	7	6	5	4	3	2	1	0
M8	Fresh Water Consumption Per Unit Output Value	9	8	7	6	5	4	3	2	1	0
M9	Reserve Production Ratio	9	8	7	6	5	4	3	2	1	0
M10	Mining Recovery Rate	9	8	7	6	5	4	3	2	1	0
M11	Washing Rate of Raw Coal	9	8	7	6	5	4	3	2	1	0

(3) Waste Discharge C3

M12	Standard Discharge Rate of Wastewater	9	8	7	6	5	4	3	2	1	0
M13	Standard Discharge Rate of Exhaust Gas	9	8	7	6	5	4	3	2	1	0
M14	Safe Disposal Rate of Hazardous Wastes	9	8	7	6	5	4	3	2	1	0
M15	Rate of Environmental Noise Reaching Standards	9	8	7	6	5	4	3	2	1	0
M16	Wastewater Discharge Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M17	Exhaust Emissions Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M18	Sulfur Dioxide Emission Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0
M19	Flue Dust Emission for Unit Output Value	9	8	7	6	5	4	3	2	1	0
M20	Solid Waste Emission Per Ten Thousand Yuan Output Value	9	8	7	6	5	4	3	2	1	0

(4) Recycle & Reuse C4

M21	Solid Waste Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M22	Comprehensive Utilization Rate of Mine Water	9	8	7	6	5	4	3	2	1	0
M23	Coal Recycling Water Ratio	9	8	7	6	5	4	3	2	1	0
M24	Comprehensive Utilization Rate of Coal Gangue	9	8	7	6	5	4	3	2	1	0
M25	Comprehensive Utilization Factor of Coal Ash	9	8	7	6	5	4	3	2	1	0
M26	Comprehensive Utilization of Coalbed Methane	9	8	7	6	5	4	3	2	1	0
M27	Collapse Land Reclamation Rate	9	8	7	6	5	4	3	2	1	0
M28	Associated Mineral Development and Utilization	9	8	7	6	5	4	3	2	1	0

(5) Environmental Protection Construction &Technological Innovation Capabilities C5

M29	Rate of Enterprise Environmental Protection Investment	9	8	7	6	5	4	3	2	1	0
M30	Environmental Protection Equipment Proportion	9	8	7	6	5	4	3	2	1	0
M31	Innovation Input Capability	9	8	7	6	5	4	3	2	1	0
M32	Technological R&D Capability	9	8	7	6	5	4	3	2	1	0
M33	Ratio of Scientific and Technical Personnel	9	8	7	6	5	4	3	2	1	0

(6) Enterprise Management & Social Benefits C6

M34	The Number of Deaths per Unit Production	9	8	7	6	5	4	3	2	1	0
M35	Enterprise Circular Economy Knowledge Training	9	8	7	6	5	4	3	2	1	0
M36	Enterprise Circular Economy Norms Construction	9	8	7	6	5	4	3	2	1	0
M37	Enterprise Information System Construction	9	8	7	6	5	4	3	2	1	0
M38	Employee Awareness about Environmental Protection	9	8	7	6	5	4	3	2	1	0
M39	Enterprise Brand Value and Social Image	9	8	7	6	5	4	3	2	1	0

Appendix 8 Expert Consultation Questionnaire for Determining Index Weight of Paper-making Enterprises Circular Economy

Dear expert:

Hello, this questionnaire's purpose is to determine index weight of established elementary evaluation index system.

Please according to your experience and follow the scoring method given below, to fill the appropriate score in the survey form. The results of this survey will serve as an important basis for establishing the index system.

Instructions:

15. The elementary index system contains 6 state layers C1~C6 and 35 variable Layers M1~M35 (shown in Table1) Due to the establishment of the evaluation index system for papermaking enterprises is based on the enterprise index system, individual indices have been added or modified. Therefore, this questionnaire is only for the index level.
16. The choice in the questionnaire is to judge the importance of the following propositions. It is a single choice question. Please mark"√"on the selected number. The options "9, 8, 7, 6, 5, 4, 3, 2, 1, 0" means that you think the importance of the corresponding index. The larger the number is the higher degree importance, and the smaller the number is the lower the degree importance.

Table1 Evaluation Index System for Circular Economy of Papermaking Enterprises

	Indexes	
Economic Benefits C1	Growth Rate of Sales Revenue	M1
	Net Return on Assets	M2
	Economic Output Density	M3
	Economic Benefits from the Implementation of Circular Economy	M4
Resource & Energy Consumption C2	Fiber Raw Materials Consumption per Unit Paper Production	M5
	Comprehensive Energy Consumption per Unit of Paper	M6
	Fresh Water Consumption per Unit of Paper	M7
	Enterprise Clean Energy Utilization Rate	M8
	Recycled Materials Rate in Raw Materials	M9
	Raw Material Utilization Efficiency	M10
Waste Discharge C3	Standard Discharge Rate of Wastewater	M11
	Standard Discharge Rate of Exhaust Gas	M12
	Safe Disposal Rate of Hazardous Wastes	M13
	Wastewater Discharge per Unit of Paper	M14
	COD Emissions per Unit of Paper	M15
	Exhaust Emissions per Unit of Paper	M16
	Dust Emissions per Unit of Paper	M17
	Sulfur Dioxide Emissions per Unit of Paper	M18
	Solid Waste Emissions per Unit of Paper	M19
Recycle & Reuse C4	Alkali Recovery Rate	M20
	Wastewater Comprehensive Utilization Rate	M21
	Solid Waste Comprehensive Utilization Rate	M22
	Waste Paper Products Comprehensive Utilization Rate	M23
	White Mud Comprehensive Utilization Rate	M24
	Waste Heat Utilization Rate	M25
Environmental Protection Construction &Technological Innovation Capabilities C5	Rate of Enterprise Environmental Protection Investment	M26
	Environmental Protection Equipment Proportion	M27
	Innovation Input Capability	M28
	Technological R&D Capability	M29
	Ratio of Scientific and Technical Personnel	M30
Enterprise Management & Social Benefits C6	Enterprise Circular Economy Knowledge Training	M31
	Enterprise Circular Economy Norms Construction	M32
	Enterprise Information System Construction	M33
	Employee Awareness about Environmental Protection	M34
	Enterprise Brand Value and Social Image	M35

(1) Economic Benefits C1

M1	Growth Rate of Sales Revenue	9	8	7	6	5	4	3	2	1	0
M2	Net Return on Assets	9	8	7	6	5	4	3	2	1	0
M3	Economic Output Density	9	8	7	6	5	4	3	2	1	0
M4	Economic Benefits from the Implementation of Circular Economy	9	8	7	6	5	4	3	2	1	0

(2) Resource & Energy Consumption C2

M5	Fiber Raw Materials Consumption per Unit Paper Production	9	8	7	6	5	4	3	2	1	0
M6	Comprehensive Energy Consumption per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M7	Fresh Water Consumption per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M8	Enterprise Clean Energy Utilization Rate	9	8	7	6	5	4	3	2	1	0
M9	Recycled Materials Rate in Raw Materials	9	8	7	6	5	4	3	2	1	0
M10	Raw Material Utilization Efficiency	9	8	7	6	5	4	3	2	1	0

(3) Waste Discharge C3

M11	Standard Discharge Rate of Wastewater	9	8	7	6	5	4	3	2	1	0
M12	Standard Discharge Rate of Exhaust Gas	9	8	7	6	5	4	3	2	1	0
M13	Safe Disposal Rate of Hazardous Wastes	9	8	7	6	5	4	3	2	1	0
M14	Wastewater Discharge per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M15	COD Emissions per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M16	Exhaust Emissions per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M17	Dust Emissions per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M18	Sulfur Dioxide Emissions per Unit of Paper	9	8	7	6	5	4	3	2	1	0
M19	Solid Waste Emissions per Unit of Paper	9	8	7	6	5	4	3	2	1	0

(4) Recycle & Reuse C4

M20	Alkali Recovery Rate	9	8	7	6	5	4	3	2	1	0
M21	Wastewater Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M22	Solid Waste Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M23	Waste Paper Products Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M24	White Mud Comprehensive Utilization Rate	9	8	7	6	5	4	3	2	1	0
M25	Waste Heat Utilization Rate	9	8	7	6	5	4	3	2	1	0

(5) Environmental Protection Construction &Technological Innovation Capabilities C5

M26	Rate of Enterprise Environmental Protection Investment	9	8	7	6	5	4	3	2	1	0
M27	Environmental Protection Equipment Proportion	9	8	7	6	5	4	3	2	1	0
M28	Innovation Input Capability	9	8	7	6	5	4	3	2	1	0
M29	Technological R&D Capability	9	8	7	6	5	4	3	2	1	0
M30	Ratio of Scientific and Technical Personnel	9	8	7	6	5	4	3	2	1	0

(6) Enterprise Management & Social Benefits C6

M31	Enterprise Circular Economy Knowledge Training	9	8	7	6	5	4	3	2	1	0
M32	Enterprise Circular Economy Norms Construction	9	8	7	6	5	4	3	2	1	0
M33	Enterprise Information System Construction	9	8	7	6	5	4	3	2	1	0
M34	Employee Awareness about Environmental Protection	9	8	7	6	5	4	3	2	1	0
M35	Enterprise Brand Value and Social Image	9	8	7	6	5	4	3	2	1	0

Appendix 9 Questionnaire Survey of Comprehensive Evaluation

Scoring Sheet (Please mark "○" in your answer) (power enterprise as an example)

Item	Index	Excellent	Good	Fair	Poor
Economic Benefits U_1	Growth Rate of Sales Revenue				
	Net Return on Assets				
	Economic Output Density				
	Economic Benefits from the Implementation of Circular Economy				
	Non-power Output Value Proportion				
Resource & Energy Consumption U_2	Standard Unit Coal Consumption for Power Generation				
	Standard Unit Coal Consumption for Power Supply				
	Water Consumption for Unit Product				
	Comprehensive Station Service Power Consumption Rate				
	Oil Consumption for Unit Product				
	Energy Utilization Efficiency				
	Annual Heat-to-electric Ratio				
Waste Discharge U_3	Standard Discharge Rate of Wastewater				
	Standard Discharge Rate of Exhaust Water				
	Safe Disposal Rate of Hazardous Wastes				
	Rate of Environmental Noise Meeting Standards				
	Flue Dust Emission for Unit Product				
	Sulfur Dioxide Emission for Unit Product				
	Nitric Oxide Emission for Unit Product				
	Ash Residue Production for Unit Product				
	Wastewater Production for Unit Product				
Recycle & Reuse U_4	Comprehensive Repeated Utilization Factor of Domestic Sewage				
	Comprehensive Repeated Utilization Factor of Industrial Wastewater				
	Comprehensive Utilization Factor of Desulfurization Gypsum				
	Comprehensive Utilization Factor of Coal Ash				
	Comprehensive Utilization Factor of Bottom Ash				
	Comprehensive Utilization Factor of Exhaust Heat				
Environmental Protection Construction &Technological Innovation Capabilities U_5	Rate of Enterprise Environmental Protection Investment				
	Enterprise Eco-environmental Transformation Potentials				
	Innovation Input Capability				
	Technological R&D Capability				
	Proportion of Scientific and Technical Personnel				
Enterprise Management & Social Benefits U_6	Enterprise Circular Economy Knowledge Training				
	Enterprise Circular Economy Norms Construction				
	Enterprise Information System Construction				
	Employee Awareness about Environmental Protection				
	Enterprise Brand Value and Social Image				